Eos, Transactions, American Geophysical Union

Vol. 65, No. 37, Pages 689–704

September 11, 1984

Tectonophysics

On the Evolution in History of the Concept of the Auroral Oval

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It is shown in this review that the concept of auroral arcs forming one or more complete rings encircling the polar cap was very well accepted in the 18th century. This idea was elaborated further throughout the 19th century but then disappeared from the scientific scene for almost 80 years owing to the promotion of the auroral zone as a better frame of reference in auroral research. It is pointed out that the auroral zone was a dead end more influenced by the prevailing ideas of the last century than a product of profound physical reasoning. Finally, the importance of historical reviews in the field of science is stressed to learn to appreciate the often well-developed ideas of our predecessors and thereby avoid long periods of wandering in darkness, as had happened in the auroral zone.

Introduction

It has often been stated that one of the greatest achievements during IGY was the discovery of the auroral belt by Feldstein [*Feldstein*, 1963, 1964*a,b*, 1967]. Feldstein's results showed that the aurora at any instant is distributed in an oval zone around the polar cap, a zone that contracts and expands according to the overall level of disturbance in the earth's magnetosphere. However, since satellite cameras came fully into play in auroral research, it has been shown that this belt or auroral oval, as it is usually called, is close to being a circle with its center very near the geomagnetic pole [*Holzworth and Meng*, 1975]. Furthermore, Holzworth and Meng showed that the inner radius of this circular belt increased very regularly with the size of the southward component of the interplanetary magnetic field (IMF).

In this article we will look back on the past history of auroral research and show how the concept of this auroral oval or auroral ring has developed from the beginning of the 18th century until today.

Ideas of F. C. Majer in St. Petersburg

One of the first scientists to think about the auroral forms being a part of a large auroral ring encircling the polar cap was F. C. Majer when in 1728 he described a method for measuring auroral height from one observation site only [*Majer*, 1728; *Kraft*, 764]. He assumed that the auroral arcs formed a ring which had its center on the earth's rotation axis and surrounded the polar cap at a constant height. He then explained how to calculate this height by measuring the aspect angles to the crescent of the arc in the sky and to the points where the arc disappeared behind the horizon. Figure 1 reproduces typical drawings from the first half of the 18th century,clearly indicating the concept that auroral arcs were believed to be segments of larger circles [*Ramus*, 1745].

In a review from the last part of the 18th century, *Bergman* [1764] surveyed seven auroral arc observations, made by different observers, which he used to determine the auroral height according to Majer's method. His results varied between 200 and 1610 km, with an average height of 697 km. He further compared these measurements with 22 auroral height estimates derived by triangulations or based on simultaneous observations of the elevation angles of auroral arcs from two separate places, a method probably first introduced by *de Mairan* [1733]. From this last and in theory more exact method, Bergman obtained heights between 500 and 1400 km, with an average of 793 km. Although these heights were much too high, these estimates were in reasonably good agreement, when the large uncertainties are taken into account, and represented strong support for the idea that auroral arcs were parts of a complete luminous ring. Bergman, however, noticed that the crescent of some auroral arcs showed a nonzero declination from the meridional plane, which was in contradiction to Majer's assumption of the auroral ring having its center on the earth's rotation axis. Bergman did not take this into account in his calculations, which then could account for some of the discrepancies noticed. The uncertainties of the earth's radius was another factor contributing to different values. He, however, did not pursue this question any further.

Simultaneous Observations

Before *Bergman* [1764] made his calculations, however, *Wargentin* [1752] published a paper where he brought in another strong evidence for the auroral arcs being part of a continuous circumpolar ring.

In 1747 Per Kalm, a newly appointed Swedish professor in economy, who earlier used to be an assistant of the famous botanist Carl Linné, went to North America on a study tour that lasted for 4 years. His main purpose of the tour was to collect special types of seed, typical for the high latitude regions of North America, and bring them back to Scandinavia. Kalm, however, also gathered notes of auroral observations, some of which he received from Benjamin Franklin and some he made personally (such as in Philadelphia on February 16 and April 3 and 19 in 1750) [*Kalm*, 1752]. These observations were later studied by *Wargentin* [1752], who discovered that they were observed simultaneously with similar observations in Scandinavia. This led Wargentin to the following reasoning: "This shows that the northern light is spread around the earth's northern apsis, and the luminous arc which use to be situated in the north with its terminators at the eastern and western horizons, appears to be a circle or a ring in the air that encircles the earth's northern pole. This ring, which nevertheless is often fragmentary and in many ways tortous, is sometimes wider and more stretched, such that we once in a while can see the arc climbing towards our zenith and passing southwards."

Later in this dissertation, *Wargentin* [1752] indicates where the central axis of this ring may be situated: "The before-mentioned ring is not at all centered at the pole, but around a point which, at least in Europe in our time, is situated 10° or 20° to the west of true north, which is the reason why the crescent of the arc is generally situated to the NNW."

There is not much difference between this more than 200 year old description of the auroral ring and similar descriptions of movements of the auroral oval in modern literature. The difference is mainly that Wargentin was not able to see these movements in relation to the variations in geomagnetic activity.

The Auroral Ring

The concept of the auroral ring prevailed throughout the 18th century and was again mentioned in a detailed dissertation by *Jessen-Schardebøll* [1763]. He honored the work done by the Swedish group concerning the auroral circle but also questioned the reality of this concept as he pointed at difficulties in proving its existence. He in particular mentioned the variability and flightiness of the "auroral substance" as he called it: "As it flickers in the east it might extinguish in the west and the variations are so versatile that nothing can be said for certain."

Because of this unsteady behavior of the aurora, Jessen-Schardebøll maintained that it became so difficult to measure its parallax by means of simultaneous obervations from two separate places that the height measurements of de Mairan for this reason were brought into doubt.

From what is said above it is quite clear that the authors of the 18th century had a fairly modern view of the global distribution of the auroral forms. An auroral ring forming a circular zone around the polar cap with its center somewhere close to the rotation axis and varying in size and strength was almost commonplace at the beginning of the 19th century.

Hansteen Determined the Center of the Ring

In 1827, Hansteen went a step forward in localizing the center of the auroral ring as he claimed that it was situated somewhere north of Hudson's Bay [*Hansteen*, 1827], and he presented an illustration to his article (Figure 2) which must be one of the first ever drawn of the auroral ring. This somewhat precise localization of the "auroral pole," a term which *Nordenskiöld* [1880–1881] later coined, was of course related to the very extensive studies made by Hansteen of the earth's magnetic field [*Hansteen*, 1819, 1825]. He was able to show that the magnetic field was nearly vertical at a point between 71° and 72° northern latitude and about 99° west of Greenwich. As he realized that the magnetic field had a strong guiding effect on the auroral forms, he assumed that this point was the center of the auroral ring. He, however, also believed that the earth's magnetic field had four poles, two in the northern and two in the southern hemisphere. The second pole in the northern hemisphere he believed to be located somewhere in Siberia, and therefore he thought another auroral ring was present there. Under these circumstances he maintained that the auroral ring did not necessarily encircle the whole polar cap, but could actually cover a much smaller area. In fact Hansteen reported that he had seen twice from Christiania (Oslo) that the aurora formed almost a complete loop or an ellipse in the sky [*e.g. Loomis*, 1866]. Although Hansteen was mistaken in his conclusion of the four magnetic poles, there is no doubt that he contributed greatly to the localization of the geomagnetic north pole near Hudson's Bay. Furthermore, he made it very conceivable that the magnetic field played an important part in forming the auroral ring and that its center therefore was related to this pole.

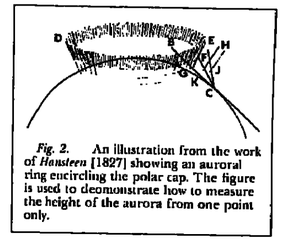

Fig. 2. An illustration from the work of *Hansteen* [1827] showing an auroral ring encircling the polar cap. The figure is used to deomonstrate how to measure the height of the aurora from one point only.

An Auroral Ellipse

In their report from an expedition to Bossekop in Finnmark, Norway, *Lottin, and Bravais* [1838] had maintained that the auroral arcs did not form a great circle around the polar cap. *Loomis* [1866] surveyed the observations of the French expedition to Bossekop and concluded that "Careful measurements made at five or six points of some of the most remarkable arcs show that, except near the horizon, they may be regarded as portions of small circles parallel to the earth's surface. Near the horizon there is sometimes a sensible deviation from this circular form, and the appearance is sometimes that of a portion of an ellipse, the extremities of the arc being bent inward."

One of the most extensive height measurements of the aurora based on the concept of the auroral ring was carried through by *Fearnley* [1859]. He based his concept of the auroral ring on the following reasoning: "One noticed that the regular arc which can often be seen (in our district) in the north, more seldom in the south,. . .had its uppermost point in the magnetic meridian which in fact divides the arc into equal halves."

From these circumstances, he reached the following conclusion "that an arc of the northern light is limited by the horizon but forms a part of a complete illuminated ring which at some height above the earth surface encircles the magnetic pole as it cuts the magnetic meridian at a right angle everywhere and follows the magnetic parallel accordingly."

Fearnley [1859] made altogether 21 height measurements of auroral arcs observed from Christiania (Oslo) and arrived at an average height of 207 km. According to Fearnley's theory, the center of the ring was not a needed parameter in his formula, but, on the other hand, a good knowledge of the earth's radius and the magnetic declination at the site of observation was crucial.

The Pole of the Northern Light

Nordenskiöld, who was the first ever to travel through the north-east passage by the vessel *Vega*, made, together with his assistants, many observations of the aurora. In his accounts of the voyage of *Vega*, he also included a chapter devoted to this phenomenon which he illustrated with some drawings of peculiar auroral forms being very regular segments of a circle. He gave the following comments to this circular shape: "...the common arc as it soon became called onboard the ship, changed so very little in position and was so regular in its form that one inevitably was led to believe that it belonged to a steady or almost steady ring of light situated in the upper part of the atmosphere." [*Nordenskiöld*, 1880–1881]. He further expanded on this conception of an auroral circle [*Nygren and Silén*, 1982]: "Our earthglobe is even during the years of auroral minimum crowned by a continuous single, double, or multiple circle of light with its lower edge lying about 200 km—that is, about 0.05 earth's radii—above the surface of the earth and with its center, the auroral pole, being located slightly below the earth's surface, somewhat to the north of the magnetic pole. The circle, being 2000 km or 0.3 earth's radii of its diameter, is directed perpendicular to the earth's radius passing through its center. I have given this circle of light the name auroral glory, since both its shape and outlook resemble the glory surrounding a saint's head. The light of this halo

Article *(cont. on p. 706)*

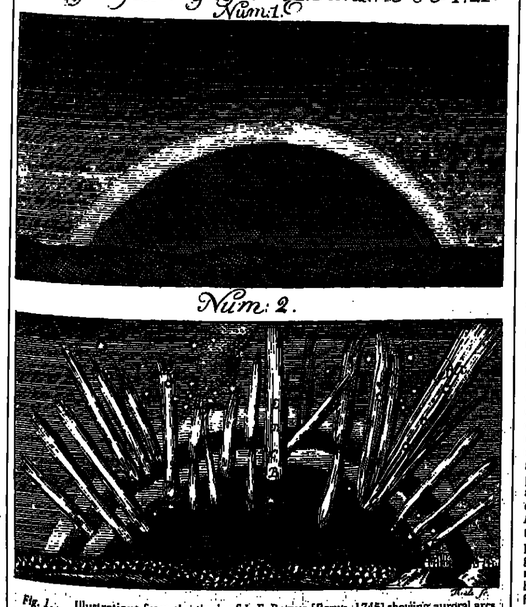

Fig. 1. Illustrations from the thesis of J. F. Ramus [*Ramus*, 1745] showing auroral arcs as circular segments.

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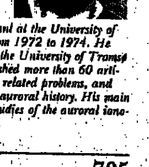

Article *(cont. from p. 705)*

never radiates, but it is more like a light seen through a piece of ground glass. When the auroras are intensified, the size of the auroral glory becomes variable: then double or multiple arcs with a common center are formed. Quite seldom, crossing arcs may be seen."

Nordenskiöld's drawing of this auroral circle, which is reproduced in Figure 3 of *Nygren and Silén* [1982], shows a very regular zone centered somewhere in the northern part of Greenland and surrounding the polar region.

As Nordenskiöld used Majer's method to derive the height of the auroral arcs, it was important for him to find the center of the circle. His reasoning when searching for this center then was as follows [*Nordenskiöld*, 1880–1881]: "But because of the relationship which has been known to exist between the northern light and the magnetism ever since the days of Celsii and Hiorter, and especially because of the fact that the crescent of the auroral arcs always and everywhere is situated close to the magnetic meridian, it is clear that one has to search for the center of the auroral glory in the neighborhood of the magnetic pole."

To determine this auroral pole more exactly, he took advantage of the theory of Gauss, and according to this the geomagnetic pole was located at 73°21'N latitude and 93°56'W longitude [*Erman and Petersen*, 1874].

From this short summary of Nordenskiöld's work it is quite evident that he had a conception of an auroral ring being very similar to the auroral oval introduced to geophysics in the 1960's [*Feldstein*, 1963, 1964*a*, *b*] and almost identical to the circular zone derived by *Holzworth and Meng* [1975] for the instantaneous distribution of the aurora around the polar cap.

Almost contemporary to the work of *Nordenskiöld* [1880–1881] was the work of *Tromholt* [1885]. Tromholt also discussed the auroral ring and made an illustration (figure 3), which clearly demonstrated why this ring often was called the "auroral glory." He also pointed out that this ring could move north or south and that this motion in some respect was related to variations in the solar sunspot cycle and the geomagnetic activity, an idea he had obtained from the work by Weyprecht, the great inspirator of the First International Polar Year [*e.g., Tromholt*, 1885]. Tromholt also, however, indicated that individual auroral forms could be parts of different rings centered at slightly different points along the geomagnetic axis [*Tromholt*, 1885].

Birkeland Demonstrated the Auroral Ring

To demonstrate his auroral theories, *Birkeland* [1901, 1913] produced by his famous terrella experiment luminous bands around the poles of a magnetized sphere suspended in a vacuum chamber in the laboratory (Figure 4). These bands when scaled properly reminded Birkeland in their behavior and structure very much of the naturally occurring auroral forms. He also showed that the position of the luminous ring, which he called the polar ring, changed by varying the magnetization of the terrella or by moving the magnetic pole with respect to the direction of the stream of cathode rays used to produce the luminosity. Based on the analogy with the natural situation, he then maintained that since the earth's rotation axis and the magnetic axis of the globe are not aligned, the earth would rotate underneath the polar ring in the course of a day, and the relative position between the polar ring and an observing site would change accordingly.

Furthermore, he also demonstrated that the size of the polar ring would vary with the intensity of the discharge current producing the cathode rays and thereby made it probable that the polar ring in the natural case would react according to the outside geomagnetic disturbance. Any better experimental evidence for the existence of the auroral ring could hardly be presented at the beginning of this century.

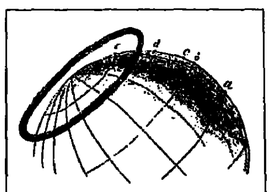

Fig. 3. The auroral ring or auroral glory as illustrated by *Tromholt* [1885].

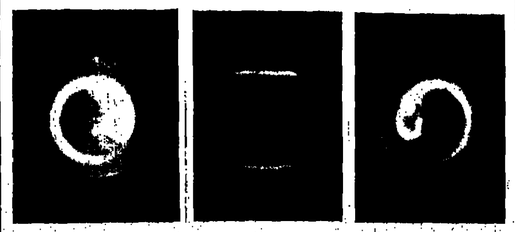

Fig. 4. A picture of some of the many polar rings as produced by *Birkeland* [1913] with his terrella experiment.

Discussion and Comments

It should, from the preceding, be rather well documented that scientists in the middle of the 18th century had a fairly precise conception of the auroral arcs forming an instantaneous continuous luminous ring encircling the polar cap in the sky. Furthermore, it has been shown that this idea was elaborated on throughout the 19th century and that the auroral ring notion was a widely accepted interpretation of individual auroral observations.

Who should become the originator of the auroral ring conception is, however, difficult to settle; certainly it is neither Carlheim-Gyllenskiöld as proposed by *Alfvén* [1967] nor Nordenskiöld or Tromholt as proposed by *Nygren and Silén* [1982]. The idea has evolved through centuries, as often is the case in geophysical science, in a combination of speculation and intuition to be substantiated finally by modern observations and deductions.

This concept of the auroral ring seems to have disappeared from the consciousness of the auroral researchers with the beginning of the 19th century. The reason for this, obviously, must be sought in the success of the introduction of the auroral zone especially conducted by the works of *Loomis* [1866] and *Frits* [1881]. The auroral zone was indeed a phantom of the prevailing spirit of the time, being dominated by collections of long data series and relatively simple statistical treatments of large data bases. Less importance was attached to the event studies that had dominated the Scandinavian school for more than 150 years. One can understand the different ways in attacking the problems of auroral research among Scandinavians and other Europeans. The Scandinavians were actually observing the phenomenon from event to event, while the other Europeans were forced to study it from annals and reports handed over to them by others. For the Scandinavians, therefore, it was more natural to seek a physical understanding of auroral events rather than to describe morphologically the global and annual distribution of the phenomenon.

Of course, scientists outside Scandinavia had attained great success with their comprehensive statistical analysis in establishing the solar cycle and the secular geomagentic variations, an analysis method that also later became a decisive factor in the manifestation of the dynamo theory. The aurora was in these days largely discussed as an optical phenomenon and, as such, as belonging to the earth's atmosphere. An auroral zone, therefore, in many ways reminded people of the climatic zones and brought the aurora into a frame of reference that satisfied the common sense. This analogy to the climatic zones, however, was based on a rather vague understanding of the fundamental cause of the aurora and overlooked the most predominant properties of the phenomenon; namely, its very irregular behavior and variability.

In hindsight, the auroral scientists had an excellent chance to confirm the concept of the auroral ring by analyzing simultaneous auroral observations obtained at the many polar stations operating during the First International Polar Year (1882–1883). Instead of accomplishing a coordinative analysis of the different data sets, however, the scientists wrote monumental national reports of their achievements in the polar region. This unique chance brought to the scene of science by the ingenious idea of Weyprecht was frittered away by national prestige and professional pride. One of the few ever to use auroral data from the First International Polar Year for case studies was Birkeland [*Birkeland*, 1901]. From these analyses he basically substantiated his theory of the horizontal auroral current in the upper atmosphere being part of a large current loop closing into space along the magnetic lines force. His work was set aside by defenders of statistical analysis of enormous collections of magnetometer recordings and completely forgotten for several decades. In a sense, the fate of the auroral ring concept and Birkeland's theory have some similarities. They both represented two very promising ways of attacking important physical problems in auroral research, and they were both based on relatively sound physical insight into these phenomena; however, they both were dispelled from the scientific scene for many decades and called to mind again in the 1960's.

There is little doubt that in auroral research the idea of an auroral zone was a dead end and that the auroral ring or circle was a far more realistic concept in understanding the auroral distribution. The physical advantage of the auroral ring or belt, as *Feldstein* [1967] called it, was also pointed out by him in the following way: "The auroral belt has thus a more definite physical sense, as it indicates an exact location of the phenomenon under consideration."

That the old idea of an auroral ring was very much on the right track may be best demonstrated when comparing the illustration of the auroral ring made by Nordenskiöld in 1880–1881 (see Figure 3 of *Nygren and Silén* [1982]) with the more up to date illustration of the auroral oval made by Holzworth and Meng in 1975. *Holzworth and Meng* [1975] pointed out that the inner and outer contours of the auroral oval as observed by optical cameras in satellites would be well fitted to circles with their centra slightly displaced from the corrected geomagnetic pole and that these centra moved slightly and the radii of the rings increased when the geomagnetic activity increased. This conclusion is indeed very similar to the descriptions of *Tromholt* [1885] made 90 years earlier.

Conclusion

We have during the last few years seen a growing interest for historical work in the field of geophysics and especially within auroral physics (*Brekke and Egeland*, 1979, 1985; *Eather*, 1980]. To make these historical reviews complete and to be sure that one has exerted justice to every past or present scientist is, of course, insurmountable and is not the main purpose of these doings. If, however, we from such historical reviews can learn to respect the work of the predecessors on our field in the light of the much less developed scientific milieu they were working in, we hope that the future can avoid entering traveling such an unpassable road as the auroral zone and losing decades of progressive thoughts.

Forum

Dynamics

"Dynamics!" she said, as she buried her head
deep in a book on tectonics.
"Must be the key to explain what we see
the ignorance of which seems to be chronic."

Convection below, then density flow
and phase changes are not withstanding;
Thermal gradient change and compositional range
are things our minds should be commanding.

With knowledge like this, we could easily kiss
off outrageous, absurd speculations
On the causes of motions that open the oceans
that lead us to wrong cogitations.

The continents move! This has been proved,
kinematics in detail has been studied;
But the structural state of each moving plate
leaves the waters less clear and more muddied.

Readers are coddled by successive models
that ignore basic physical laws.
The authors expound, but no proof can be found
that they've done more than just wave their claws.

If it's mechanically "go," then why can't they show
by making some astute assumptions
That the heat is enough or the surface too rough
to cause oceanic consumptions.

I agree with the fact, on the mantle we lack
specifics; but we can at least try
For a sensible stance, a physio-chemical glance
at the models before we throw pies.

We don't know the score, in the mantle or core
cry so many, but let us give pause . . .
Regardless of likes; Isacks, Oliver and Sykes;
Treatment's not through the symptoms, but cause!

Barbara Ransom
Department of Geology and Geophysics
University of California
Berkeley, Calif.

This was written during the author's first course in plate tectonics and may sum up one's first exposure to literature.

Lottin, M., and M. Bravais, *Voyages en Scandinavie*, pp. 170–171, Arthus Bertrand, Paris, 1838.
Majer (Meyer), F. C., De Luce Boreali, *Acad. Sci. Petropolitanae. 4*, 121, 1728.
Nordenskiöld, A. E., Vegas Färd Kring Asien och Europa, F.& G. Beijer, Stockholm, 1880–1881.
Nygren, T., and J. Silén, A. E. Nordenskiöld and the auroral oval. *Eos. Trans. AGU, 63*, 553, 1982.
Ramus, J. F., Historisk og Physisk Beskrivelse af Nordlysets forunderlige Skikkelse, natur og Oprindelse, *Proc. Acad. Sci.*, , 317–396, 1745.
Tromholt, S., *Under Nordlysets Straaler*, Gyldendal, Kjøbenhavn, 1885.
Wargentin, P., Vetenskapernas Historia, Om Nordskenet, *Proc. R. Swed. Acad. Sci.*, 161–171, 1752.

Hägd, *Proc. R. Swedish Acad. Sci.*, 193–210, 1764.
Birkeland, K., *Expédition Norvégienne pour l'étude des Aurores Boréales, Resultats des Recherches Magnétiques*, Christiania, 1901.
Birkeland, K., *The Norwegian Aurora Polaris Expedition 1902–03, II*, H. Aschehough, Christiania, 1913.
Brekke, A., and A. Egeland, *Nordlyset, Fra Mytologi Til Romforskning*, Gröndahl, Oslo, 1979.
Brekke, A., and A. Egeland, *The Northern Light: From Mythology to Space Research*, Springer Verlag, Berlin, 1983.
de Mairan, J. J., *Traité Physique et Historique de l'Aurore Boréale*, 1st ed., Pimprémerie, Paris, 1733.
Eather, R. H., *Majestic Lights*, AGU, Washington, D.C., 1980.
Erman, A., and H. Petersen, *Die Grundlagen der Gaussischen Theorie*, Berlin, 1874.
Fearnley, C. F., Hr. Fearnley fremsatte en Methode til at finde Nordlysets Højde af Observationer udførte paa et og samme Sted, som hvilede paa den Forudsætning, at en Nordlysbue har Retningen af en magnetisk Parallel, *Proc. Norwegian Acad. Sci.*, 117–149, 1859.
Feldstein, Y. I., On morphology of auroral and magnetic disturbances at high latitudes, *Geomagnet. Aeron. 3*, 183–192, 1963.
Feldstein, Y. I., Auroral morphology, I, The location of the auroral zone, *Tellus, 16*, 252–257, 1964*a*.
Feldstein, Y. I., Auroral morphology, II, Auroral and geomagnetic disturbances, *Tellus, 16* 258–267, 1964*b*.
Feldstein, Y. I., Dynamics of auroral belt and polar geomagnetic disturbances, *Planet. Space Sci., 15*, 209–229, 1967.
Fritz, H., *Das Polarlicht*, F. A. Brockhaus, Leipzig, 1881.
Hansteen, C., Untersuchungen über den Magnetismus der Erde, I, Lehman and Gröudahl, Christiana, 1819.
Hansteen, C., Forsøg til et Magnetisk Holdningskart, *Mag. Naturvidensk. 2*,203–219, 1825.
Hansteen, C., *On the polar light, or Aurora Borealis and Australis, Philos. Mag., Ann. Philos. New Ser.*, 333–334, Nov. 1827.
Holzworth, R. H. and C.-I. Meng, Mathematical representation of the auroral oval, *J. Geophys. Res. Lett., 2*, 377–380, 1975.
Jessen-Schardeböll, E. J., *Det Kongerige Norge Fremstillet Efter Deres Naturlige og Borgerlige Tilstand*, tome I, Copenhagen, 400, 1763.
Kalm, P., Några Nordsken Observerade i Norra Amerika, *Proc. R. Swedish Acad. Sci.*, 146–155, 1752.
Kraft, G. W., Observatum Meteorologicum ab 1726 usque in finem anni 1736, *Comment. Acad. Sci. Imp. Petropolitanae, 9*, 316–365, 1764.
Loomis, E., The Aurora Borealis, or polar light, its phenomena and laws, *Ann. Rep. Bd. Regents Smithson. Inst.*, 208–248, 1866.

News

Satellite Congestion

At last count, there were more than 160 satellites in geostationary orbits, circling the earth at an altitude of 37,000 km, and according to a research review published recently by the Rand Corporation, that's already too crowded. The risk of physical collisions among satellites is small, say authors Alvin L. Hiebert and William Solffrey, but there is an emerging problem with what they call "spectral and orbital congestion," the result of too many satellites and ground stations sending out too many electromagnetic signals that can interfere with one another.

The report comes at a time when the Federal Communications Commission is planning to reduce the spacing between satellites along the U.S. segment of the orbital arc so that 37 additional satellites can be squeezed into the high orbit favored for telecommunications. "As more satellites are launched and others are shifted to avoid collisions, interference problems will get more complicated," say the authors of the report.

The problem of satellite transmission interference is analagous to the effect of passing a radio broadcast tower while driving in your car. Even though your receiver is tuned to another frequency, the nearby transmitter can interfere with your signal. For commercial telecommunications satellites constantly circling the earth and drifting around within their prescribed orbits, signal interference is a nuisance. For military data satellites, it could be a danger. And proximity is not the only possible cause of interference. A satellite or ground station can even interfere with itself if a malfunction in its electronics causes a signal to travel from one spacecraft component to another.

Fortunately, someone has been trying to solve, or at least to get an analytical handle on the problem. In the past several years engineers working in the private sector, the government, and the military have developed more than 20 different computer programs designed to solve problems of "electromagnetic compatibility," and the main purpose of the Rand authors was to list and describe all these "Techniques for the Analysis of Spectral and Orbital Congestion in Space Systems," which is, incidentally, the title of their report. These specialized computer programs are designed to help groups planning to launch satellites by telling them what kinds of interference problems they can reasonably expect to encounter in geosynchronous orbit. Hiebert and Solffrey's report also deals with the vulnerability of satellites to various kinds of manmade and natural interferences, from deliberate jamming efforts to the blackouts that could be caused by nuclear explosions in space.

As a result of the Rand report, the Air Force Space Division has formed several offices to make use of the techniques for analyzing the effects of orbital crowding, and is using the information to prepare for the World Administrative Radio Conference in 1985. Sponsored by the International Telecommunications Union, an agency of the United Nations that allocates worldwide radio frequencies, this conference will be a comprehensive discussion of geostationary orbital positions and other space communications issues. In addition, the Department of Defense has begun compiling a data base on space and earth electromagnetic environments at its Electromagnetic Compatibility Analysis Center (ECAC) in Annapolis, Md., in the hope that computerized analytical tools might help to alleviate the problems of satellite congestion.

EOS

Transactions, American Geophysical Union

The Weekly Newspaper of Geophysics

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American Geophysical Union
2000 Florida Avenue, N.W.
Washington, DC 20009

Cover. The system shown in the photograph is a digital heat flow instrument package used by K. E. Louden of the Department of Oceanography at Dalhousie University. This system allows for in situ measurement of geothermal gradients and sediment thermal conductivity. The weight stand at the top of the picture houses two pressure vessels containing the electronics. A microprocessor controls the measurement, recording, and telemetering of the temperature data. A 12-kHz pinger transmits the temperature data to the surface for a real-time representation of the process. The 4-m-long sensor string encased in an oil-filled 5/16-inch stainless steel tube runs along the strength member on the left-hand side. The sensor string consists of nine equally spaced thermistors and a heater wire. The violin bow–style attachment of the string is to reduce the effective thermal disturbance by the penetration of the strength member into the sediments. This package is designed for multiple penetration probing, where the probe is pogoed along the bottom, allowing for up to 20 stations per lowering. The electronics were designed and built for Dalhousie by Bullard Laboratories at Cambridge, U.K. (This photo was contributed by D. Hebert, Department of Oceanography, Dalhousie University, Halifax, NS B3H 4J1 Canada.)

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Award Honors Duggal

Shakti P. Duggal, a widely respected member of the international cosmic ray community, was a member of the scientific staff of the Bartol Research Foundation for 22 years prior to his untimely death in 1982 at the age of 50. In his memory an award has been established by his colleagues and friends to honor outstanding work by a young scientist in the field of cosmic ray physics. The first biennial award, consisting of $1,000 and a plaque, will be presented at the 19th International Cosmic Ray Conference (ICRC), to be held in La Jolla, Calif., August 10–24, 1985.

The intent of this award is to inspire young cosmic ray scientists at an early stage of their careers. The recipient will not have attained the age of 36 on January 1 of the year of the ICRC at which the award will be presented. Subject to this limitation, any person from anywhere in the world who has contributed to the field of cosmic ray physics is eligible for consideration. Selection of the prize winner will be made by an international committee consisting of John Simpson, University of Chicago; Peter Fowler, University of Bristol; Michelle Casse, Center for Nuclear Studies, Saclay, France; Arnold Wolfendale, University of Durham; and Martin Pomerantz, Bartol Research Foundation, University of Delaware.

Nominations of potential recipients are now being solicited. Nominators are requested to send to the committee secretariat at the Bartol Research Foundation their nominee's vita and publication list, a supporting letter, and, if possible, copies of one or two of the candidate's most significant publications. The sponsor may also wish to ask one or two co-sponsors to send letters supporting the nomination to the secretariat.

Nominations, which should reach the secretariat before December 15, 1984, may be addressed as follows: Duggal Award Committee, Bartol Research Foundation of the Franklin Institute, University of Delaware, Newark, DE 19716.

Recent Ph.D.'s

Eos periodically lists information on recently accepted doctoral dissertations in the disciplines of geophysics. Faculty members are invited to submit the following information, on institution letterhead, above the signature of the faculty advisor or department chairman:

(1) the dissertation title,
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If possible, include the current address and telephone number of the degree recipient (this information will not be published).

Dissertations with order numbers, and many of the others listed, are available from University Microfilms International, Dissertation Copies, P.O. Box 1764, Ann Arbor, MI 48106.

An Examination of the Variability of Migratory Timing Statistics Estimated from Catch and Effort Observations, A. J. Hutt, Dept. of Oceanogr., Old Dominion Univ., May 1984.

An Intravenous Forecasting System for Commercial Marine Fisheries, E. J. Barth, Dept. of Oceanogr., Old Dominion Univ., May 1984.

Apparent Polar Wander Paths for the North and South China Blocks, J. Lin, Dept. of Geol. Sci, Univ. of Calif., Santa Barbara, Spring 1984.

Aquatic Geochemistry of the Particle-Reactive Radionuclides Be-7, Po-210, and Pb-210, J. F. Todd, Dept. of Oceanogr., Old Dominion Univ., May 1984.

Ashgillian and Pleylonian of the Diplograptinae (Graptolodina), C. E. Mitchell, Dept. of Geol. Sci., Harvard Univ. (S. J. Gould), November 1983.

Characterization and Stability of Phase A, A Hydrous Pressure-Dependent Phase in the System MgO-SiO$_2$-H$_2$O, A. I. Benimoff, Dept. of Appl. Sci., Coll. of Staten Isl. (C. B. Sclar), October 1984.

Depositional Modeling of Tetrahedrite in the Coeur d'Alene District, Idaho, C. J. Hackbarth, Dept. of Geol. Sci., Harvard Univ. (U. Petersen), June 1984.

Determinants for the Timing of Escapement from the Sockeye Salmon Fishery, Copper River, Alaska: A Simulation Model, H. A. Schaller, Dept. of Oceanogr., Old Dominion Univ., May 1984.

Determination of Crustal and Upper Mantle Structure from Analysis of Broadband Teleseismic P-Waveforms, T. J. Owens, Dept. of Geol. and Geophys., Univ. of Utah, August 1984.

Excitation of Low-Frequency Plasma Waves by a Conducting, Tethered Satellite, C. E. Rasmussen, Dept. of Phys., Utah State Univ. (P. M. Banks), August 1984.

Evolution of Diversity in an Adaptive Mosaic, T. D. Walker, Dept. of Geol. Sci., Univ. of Calif., Santa Barbara, Spring 1984.

Genesis of the Tungsten-Base Metal Ores at San Cristobal, Peru, A. R. Campbell, Dept. of Geol. Sci., Harvard Univ. (U. Petersen), November 1983.

Geochemistry of Fluids in the Cerro Colorado, Porphyry Copper Deposit, Panama, M. V. Raynolds, Dept. of Geol. Sci., Harvard Univ. (U. Petersen), November 1983.

Geostrophic Transport in the Warm Water Sphere of the Eastern Subtropical North Atlantic (in German), L. Stramma, Inst. für Meereskunde, Univ. Kiel (G. Siedler), Fed. Repub. of Germ., 1984.

Integrated Stratigraphy of Turbidite Deposits and the Reconstruction of the Late Cretaceous Paleogeography of the Vizcaino Basin, Baja California, Mexico, D. L. Patterson, Dept. of Geol. Sci., Univ. of Calif., Santa Barbara, Winter 1984.

Investigation of Methods for the Comparison of Timing Behavior with Application to the Pink Salmon Fisheries of Prince William Sound, Alaska, L. J. Rugolo, Dept. of Oceanogr., Old Dominion Univ., May 1984.

Keweenawan Volcanic Rocks of the Grandview Mining Area, Northwestern Wisconsin, H. M. Ali, Dept. of Geol. and Geophys., Univ. of Wisc.-Madison (C. Craddock), December 1982.

Microfracture Growth During the High Temperature Creep of Periodiite in the Presence of CO$_2$, M. R. Rovetta, Sch. of Oceanogr., Univ. of Wash., June 1984.

Nature and Origin of Refractory Inclusions in the Allende Meteorite, A.S. Kornacki, Dept. of Geol. Sci., Harvard Univ. (J. A. Wood), March 1984.

Nitrate and Non-Sea-Salt Sulfate Aerosols Over Major Regions of the World Oceans: Concentrations, Sources, and Fluxes, D. L. Savoie, Rosenstiel Sch. of Mar. and Atmos. Sci., Univ. of Miami (J. M. Prospero), May 1984.

Petrology and Diagenesis of Medium-Grained Clastic Sediments in the Back-Arc Basins of the Western Pacific, Y. I. Lee, Dept. of Geol., Univ. of Ill. at Urbana-Champaign (S. D. Klein), May 1984.

Petrology of Deep Crustal Xenoliths from the Eastern Snake River Plain, Idaho, D. J. Matt, Dept. of Geol., Rice Univ. (W. P. Leeman), May 1984.

Phytoplankton Ecology and Dynamics in the James River Estuary, Virginia, U.S.A., J. J. Fiarello, Dept. of Oceanogr., Old Dominion Univ., May 1984.

Pulsating Aurora: Photometer, Riometer and Micropulsation Coil Observations, G. B. Burns, Div. of Theor. and Space Phys., La Trobe Univ. (K. D. Cole), Australia, May 1984.

Rainfall Temporal Patterns and Runoff at Coshocton, Ohio, G. O. Chukwuma, Agr. Eng. Dept., Ohio State Univ. (G. O. Schwab), March 1982.

Source Parameters and Faulting Processes of the August 1959 Hebgen Lake, Montana Earthquake Sequence, D. I. Doser, Dept. of Geol. and Geophys., Univ. of Utah, June 1984.

Stratigraphy, Tectonics, Paleoclimatology and Paleogeography of Northern Basins of Brazil, M. V. Caputo, Dept. of Geol. Sci., Univ. of Calif., Santa Barbara, Winter 1984.

Structure, Stratigraphy, and Metamorphism of the Mount Deborah Area, Central Alaska Range, Alaska, W. M. Brewer, Dept. of Geol. and Geophys., Univ. of Wisc.-Madison (C. Craddock), December 1982.

Books

Iron-Formations: Facts and Problems

A. F. Trendall and R. C. Morris (Ed.), *Dev. in Precambrian Geol.*, vol. 6, Elsevier, New York, xiv + 558 pp., 1983, 106.00.

Reviewed by Henry Lepp

This book is similar in format to *Precambrian Iron-Formations of the World*, published in 1973 as a special issue of *Economic Geology* (vol. 68, no. 7). Both have 16 papers and begin with descriptions of iron formations or iron districts followed by topical papers on various aspects of the iron formation problem. New basic data on Precambrian iron bearing and associated rocks has continued to accumulate since 1973, and the present volume admirably fills the need to compile this widespread information and to reexamine these enigmatic rocks in the light of new discoveries.

Iron Formations: Facts and Problems is almost twice as long as its predecessor. Moreover, the descriptive section (80% of the book) is limited to five large iron districts, which provides space for exceptionally thorough syntheses. The introduction by Alex Trendall clarifies the purpose and scope of the book and presents a thoughtful review of problems associated with the nomenclature and classification of Precambrian iron bearing rocks. G. B. Morey begins the descriptive section with a detailed analysis of the Animikie Basin including its regional setting, geochronology, and paleoenvironments. A. F. Trendall updates and summarizes the extensive work that he and others have done in the Hammersley Basin, and A. D. T. Goode, W. D. M. Hall, and J. A. Bunting describe the geology, structure, and iron formations of the adjoining Nabberu Basin. The paleoenvironmental settings of iron formations in the Transvaal-Griqualand West districts are ably covered by N. J. Beukes. G. A. Gross and I. S. Zajac present a thorough review of the geology, iron formations, and depositional environments in basins marginal to the Ungava craton including the Labrador Trough.

Nine contributions are topical. R. Davy's review of chemical compositions of iron formations is heavily based on Hammersley analyses. The rather scanty data on rare earth elements in iron sediments are summarized and interpreted by B. J. Fryer. E. C. Perry adds considerable new information on oxygen isotopes and discusses problems in data interpretation. M. R. Walter and H. J. Hofmann survey the paleontology of Precambrian iron sediments and conclude that neither stromatolites nor convincing evidence for microfossils are known for Archaean iron formations. Preston Cloud reviews and modifies his model for the genesis of banded iron formations. A lengthy and detailed contribution by C. Klein looks at the diagenesis and metamorphism of iron formations in the light of new chemical and mineralogical data. H. L. James after bravely assessing the ages and tonnages of major iron formations offers explanations for their distribution in time and space. W. E. Ewers' paper on chemical factors in deposition and diagenesis focuses on the Dales Gorge Member of the Brockman Iron Formation. Like other authors, Ewers "would have wished to have transferred more of this topic from areas of opinion and controversy into areas of reasonable certainty." A comprehensive analysis of the supergene alteration of banded iron formations by R. C. Morris ends the volume.

A short paper by Heinrich Holland in the 1973 work titled "The Oceans: A Possible Source of Iron in Iron-Formations" appears to have had a marked effect on the present volume. As was noted by Harold James in the foreward, almost all contributors have accepted the idea of an ocean reservoir for the iron and silica. How the iron, silica, and other constituents were precipitated from this reservoir is another matter. Explanations are highly subjective and focus chiefly on possible mechanisms for the precipitation of banded cherty oxide iron formations. Of course, all iron formations are not banded, nor do all contain oxides as the principal or primary iron minerals. Although chert is the main non-iron component, some iron formations contain significant quantities of carbonate gangue. In spite of their textural and mineralogic variability, most iron formations consist of approximately equal parts of iron and non-iron minerals. How equal parts of such dissimilar elements were laid down in what appear to be diverse environments remains a major puzzle. Although this book does not have all the answers, its excellent coverage of new geologic, chemical, paleontologic, and mineralogic data should be most useful in stimulating further research.

Authors of the descriptive chapters were asked not to focus on the iron formations but to show how these rocks related to the development of the various depositional basins. Their contributions on six widespread and well preserved segments of early crust thus represent significant contributions to Precambrian geology.

The printing and illustrations are generally of high quality, and there are very few errors. Chapter references are extensive, and the index is most useful. This book should be in the libraries of all geologists interested in the Precambrian, but the high cost may impede its wide distribution.

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Drinking Water Supplies: Protection Through Watershed Management

Raymond J. Burby, Edward J. Kaiser, Todd L. Miller, and David H. Moreau, Ann Arbor Science, Ann Arbor, Michigan, 1983, xxii + 273 pp., $39.95.

Reviewed by G. William Page

The practice of purchasing land to protect surface water supply sources is rarely practical today. This is particularly true near urban areas. Therefore, *Drinking Water Supplies* attempts to provide an action-oriented guidebook on how to develop and implement watershed management strategies to protect surface water supplies from contamination under the constraints of today's economic, legal, institutional, and political conditions. The book succeeds in providing a very clear and useful guide to the process of developing such a strategy. It should be helpful to small and moderate-sized water supply systems and local governments interested in taking action to protect their surface water supply sources.

Most of the book is devoted to process. That is, it is a detailed checklist of the factors that must be considered, the studies that must be completed, and the steps that must be taken. This is a substantial contribution to the literature. While there are many works that touch on protecting water supply sources, they are generally either very broad in focus or they are more technical and more narrowly focused. Some examples of broadly focused works are Dunne and Leopold, *Water in Environmental Planning* and Goodman, *Principles of Water Resources Planning*. Examples of related but more technical and narrowly focused works include Milliken and Taylor, *Metropolitan Water Management*; Pojasek, *Drinking Water Quality Enhancement Through Source Protection;* Greenberg and Hordon, *Water Supply Planning;* and Whipple, *Urbanization and Water Quality Control*. All of these references are good and useful to the task of protecting water resources, but *Drinking Water Supplies* provides the most comprehensive and clearly elaborated approach to developing, implementing, evaluating, and updating an effective multidimensional strategy.

My major criticisms of *Drinking Water Supplies* concern issues of omission. The group for whom this book will have the greatest use are water supply system and local government officials charged with providing potable water to small or moderate-size municipalities in the United States. More than half of the small and moderate-size municipalities rely on groundwater for their source of water, and this book does not address protecting groundwater sources. While many of the land use planning methods designed to protect watersheds are also useful in protecting aquifer recharge areas, this book does not describe differences in groundwater and surface water systems, nor does it attempt to suggest differences in strategies to protect these different sources of water. A volume addressing this issue would be a welcome companion to the book under review. My second disappointment with the book is the lack of attention to the special problems of protecting water sources from contamination by toxic substances. The authors discuss this problem, but seem to assume that measures to protect watersheds from conventional pollutants will be sufficient to protect watersheds from pesticides, heavy metals, industrial solvents, and other toxic chemicals. Because of the danger to public health caused by extremely low concentrations of these substances, this issue demands much greater attention in developing watershed management plans.

Of particular interest in *Drinking Water Supplies* are the results of a survey of present watershed management practices and the lists of techniques which can potentially be included in a comprehensive strategy to protect water sources. The results of the national survey of surface water systems which excluded both very large and very small systems provide interesting reading, especially lists of the problems perceived to be the most serious and the techniques thought to be the most effective. The discussion of potential approaches and techniques is comprehensive and very useful. In general the book provides ample references to additional and more detailed sources of information.

G. William Page is with the Department of Urban Planning and the Center for Great Lakes Studies, University of Wisconsin-Milwaukee, Milwaukee, WI 53201.

Crystal Symmetry: Theory of Colour Crystallography

M. A. Jaswon and M. A. Rose, Ellis Horwood Ltd., Chichester, England, 190 pp., 1983.

Reviewed by Charles W. Burnham

Geophysicists concerned with physical properties of crystalline solids ought to have a working familiarity with space group symmetries, especially as the symmetries of atomic arrangements affect the directional behavior of these properties. While an understanding of the operational characteristics of the 230 three-dimensional space groups will suffice for most applications, magnetic properties can reflect more complex symmetries that hinge not only on atomic position but on orientation of magnetic moment as well. With "spin" variability included, the total symmetry can fall into any one of 1191 magnetic—or color, black and white, or Shubnikov—space groups distributed among 58 magnetic point groups.

Although this book emphasizes color crystallography in its title, it includes an exposition of the underlying noncolor crystallography, assuming no prior crystallographic knowledge. Its 14 chapters are divided into three parts: part 1 with four chapters on crystallographic point groups; part 2 with four chapters on space lattices; and part 3 with six chapters on space groups. Only the last chapter of each part enumerates the groups containing color operators. There are nine short appendices, some of which contain important basic material that the novice to this subject will need to master early on. The text might be classified as an annotated enumeration of all the various symmetry groups; rigorous derivations are scant, and applications, examples, and problems are totally absent. The approach is primarily group theoretical with a smattering of matrix representations and linear algebra and a few geometric representations that provide some visual reinforcement. The text is generally terse and in some cases not well organized. For example, the first encounter with the important X operator is in Table 1.2, whereas it is not discussed in the text until the end of chapter 2, yet some other rotoinversions appear in chapter 1. The common misperceptions that crystal systems are defined on the basis of lattice geometry rather than presence of a certain minimal set of rotations is perpetuated in chapter 6. Thus the reader will be unaware that a crystal whose lattice has a square prismatic unit cell, for example, is not tetragonal unless it can be demonstrated that its atomic arrangement possesses fourfold symmetry in one direction; the lattice itself is not inconsistent with any lesser symmetry.

The geophysicist concerned with the implications that symmetry has for atomic structure and therefore on physical properties will not find this book helpful. The problem of determining symmetry is not considered at all. I can recommend this book only to those scientists already well conversant with space groups who would like to see an efficient, somewhat elegant, primarily group theoretical enumeration of all crystallographic color point groups, translation groups, and space groups.

Charles W. Burnham is with the Department of Geological Sciences, Harvard University, Cambridge, Mass.

The Exploration of Outer Space With Cameras

M. M. Mirabito, McFarland, Jefferson, N. C., 1983. vi + 170 pp.

Reviewed by Michael J. S. Belton

This monograph "chronicles the use of television cameras and other visual imaging systems by NASA on unmanned outer space probes and in the exploration of the Solar System's planetary bodies."

The book is technically well organized and a nicely printed volume with the unfortunate exception of the 32 illustrative plates that are of nothing less than abysmal quality. Included in the selection of pictures are a number of classic Voyager color photographs, but the high contrast black and white renditions in this volume convey little of their original beauty or information content.

The contents are organized into 11 chapters that cover, with detailed descriptive material, imaging systems on NASA spacecraft starting with the Ranger moon probes through Voyager (chapters 1–6). There is a very brief discussion of the need for calibration and image processing (chapter 7); another brief (chapter 8) and, in my view, superficial exposition on what subsequent scientific analysis of the returned images has yielded; a chapter on proposed missions; and a brief chapter on spin-off from these NASA projects to applications in medicine, astronomy, and the communications industry. The last chapter—only one page long—on Implication and Conclusions best illustrates, I think, the weakness of the book: The author seems to have great difficulty in expressing his excitement with the subject to any great depth or intellectual conviction. His conclusion that "the next step is manned flight to these worlds" springs out of nowhere and, although this reviewer expects that this might be a popular conclusion with many of the readers for whom the book was designed, it does not seem to connect in any logical way to the subject matter.

The book has an extensive section (31 pages) of chapter notes, references, and a good bibliography. The latter includes a wide range of material, from congressional subcommittee minutes to major journal articles, that is useful in itself. Apart from its brevity, which sometimes leaves one with an impression of superficiality, there are also some real problems with the text. For example, the author occasionally makes analogies with simpler phenomena in everyday experience in order to clarify a difficult point. But this rarely seems to work. In one case, an attempt to explain the origin of ringlets in Saturn's ring system, he uses an analogy based on the behavior of using charged iron filings on the bottom of a flat disk. The result is nothing less than a total obfuscation. This reviewer will stick to Goldreich and Tremaine.

What this reviewer missed most, while reading this "chronicle" of great human achievements, was any identification of the camera systems and projects with the real, individual, people who were involved. Who were the engineers and scientist that put the cameras, design criteria, sequences, etc., together? Who set the priorities? Who made the discoveries? What were their disappointments and tragedies? History without people is surely dull. The book is recommended only to those who have a peripheral, nontechnical, interest in the subject matter.

Michael J. S. Belton is with the Kitt Peak Observatory, Tucson, Ariz.

Geological Evolution of the Earth During the Precambrian

L. J. Salop (transl. by V. P. Grudina), Springer-Verlag, New York, 459 pp., 1983, $65.80.

Reviewed by Edward S. Grew

Salop's book is a review of geologic history during the Precambrian, with an emphasis on subdivision of Precambrian time, worldwide comparison of stratigraphic sequences, and characterization of tectonic regimes. The author cautions in the Preface that the book is not a compilation; the problems discussed here are those with which the author was concerned personally." Nonetheless, the book is an ambitious synthesis of nearly 3500 million years (my) of earth's history. Salop proposes a division of the Precambrian into 5 eras (time span before present in my): Katarchean (≥3500), Paleoprotozoic (3500–2600), Mesoprotozoic (2600–1900), Neoprotozoic (1900–1000), and Epiprotozoic (1000–650). The sub-era Eocambrian (650–570) is provisionally included in the Paleozoic Era. Each era is characterized by distinctive lithostratic complexes and is bounded by diastrophic (orogenic) cycles of global extent. After an introductory chapter in which the principles of the division are discussed, Salop devotes a chapter to each era and to the Eocambrian and concludes in the eighth chapter with a synthesis. Chapters 2–7 consist of two parts: "Rock Records" and "Geologic Interpretation of Rock Record." The first part is largely a description of the lithostratigraphic complexes, including correlation of stratigraphic columns, from most of the world's Precambrian complexes. The second part discusses the physical and chemical environment on the earth's surface during the era covered by the chapter, sedimentation environment, life, tectonic regime, principal stages of geologic evolution, and other topics appropriate to a particular era. While Salop devotes more attention to Precambrian terrains exposed in the Soviet Union, he covers in considerable detail all the world's Precambrian rocks for which sufficient information is available. Consequently, the reader will find in this book a wealth of factual material. Salop is to be commended for pulling together and distilling a large amount of information from a vast literature (24 pages of references, although only a handful more recent than 1980).

Perhaps more important for many readers, however, is the exposition of a different perspective on Precambrian rocks. Salop's division of the Precambrian is based on his view of the Precambrian as a succession of cycles that "happens against the background of a directed and irreversible evolution of the earth." (p. 379). Each large geologic cycle ("megacycle"), represented by an era, includes a distinctive sedimentary environment (e.g., glacial deposits in the Epiprotozoic) and tectonic regime (e.g., mantled gneiss domes in the Paleoprotozoic). These cycles, like the orogenic cycles, are also worldwide in scope and appear in all exposed Precambrian terrains of appropriate age. As a consequence of this view, the fundamental criteria for correlating Precambrian units are lithological, with consideration also given to structural and metamorphic features. In addition, Salop makes use of radiometric ages (surprisingly, the Sm-Nd isotope method is not mentioned) in correlating Precambrian events, particularly in timing the important orogenic cycles. However, isotopic ages are in most cases a secondary consideration. In the case of the Isua Supracrustals of West Greenland, Salop acknowledges that the radiometric dates near 3800 my are convincing evidence for a Katarchean age of the Isua rocks and that these dates override lithologic and metamorphic considerations, notably presence of conglomerates and greenschist to amphibolite-facies metamorphism, which are indicative of a Paleoprotozoic age. For the general case, however, granulite-facies metamorphism, in part retrograded under amphibolite-facies conditions, and accompanied by metasomatic or anatectic enderbites and charnockites, are characteristic of Katarchean rocks and with rare exceptions, confined to this era. Thus, North American geologists will be surprised to see the granulite-facies Grenville Group included in the Katarchean because of this group's metamorphic grade and lithologic similarity to Katarchean marble and calc-silicate–bearing units in the Aldan Shield and Lake Baikal areas of Siberia. Salop attributes the Grenville ages near 1000 my to intense thermal-tectonic reworking of a preexisting granulite-facies complex. Students of Precambrian geology may not share Salop's scepticism regarding the usefulness of isotopic data in determining ages of sedimentation, volcanism, and of the original (hence, most important, in Salop's view) metamorphism. On the other hand, Salop's interpretation that most high-grade rocks are old and have undergone repeated metamorphic and deformational events has considerable validity. "Isotopic rejuvenation," Salop's expression for disturbances in isotopic systems by later events, is characteristic of Precambrian high-grade metamorphic rocks, even of the Sm-Nd system in some cases. In this reviewer's experience, isotopic rejuvenation has hindered attempts to determine the crust formation and original metamorphic ages of many amphibolite- and granulite-facies rocks in the Precambrian shield of east Antarctica.

Other interpretations forwarded by Salop, however, do not appear as firmly based in theory and observation as his outlook on isotopic ages. For example, Salop argues that plate tectonics is not applicable to the Precambrian (except possibly in the "Late Precambrian," p. 407, here unspecified). As an alternative explanation for the origin of the ocean basins, he supports the suggestion that these formed by "subsidence of the lower part of the crust into the upper mantle" (p. 402) in conjunction with limited expansion of the earth. Moreover, this reviewer finds that Salop's terminology for the eras is cumbersome and confusing, particularly the term "Protozoic," which sounds almost like "Proterozoic." His rigid classification scheme does not allow for either widely different evolutions in different parts of the world, nonsynchronization of orogenic events and sedimentological environments, or for repetition of certain phenomena, such as granulite-facies metamorphism in post-Katarchean time.

By and large, V. P. Grudina's translation from the Russian has produced a readable English text. However, a few odd words and phrases have escaped the editors, for example, "sensibility" for "sensitivity" (p. 76), "submergence of minor fold bends" (p. 40), and "general unregulated situation" (p. 66). An occasional passage is incomprehensible. Typographical and spelling errors occur about once every five pages. Reproduction of the figures (all but one are line drawings) is good. However, the larger-scale maps are without geographic coordinates or an index map, so that the reader is at a loss to locate these maps in their larger context.

In sum, the Precambrian specialist would be well advised to add Salop's book to his reference library, but the more general geologist may find the price a bit high for an alternative view of Precambrian geology.

Edward S. Grew is a Humboldt-Stipendiat at the Ruhr-Universität Bochum, Institut für Mineralogie, Postfach 102148, D-4630 Bochum 1, West Germany.

Classified

Department Head of Plant Sciences/University of Nevada Reno. The College of Agriculture, University of Nevada Reno, is seeking applicants for this well-earned tenure track position. The Department has nineteen faculty and conducts teaching, research and extension programs in the areas of agronomy, horticulture and integrated pest management. A Ph.D. in a plant science related discipline and evidence of administrative and leadership abilities are required. Closing date for applications is October 15, 1984. The position is available January 1, 1985. Contact: Dr. Elwood Miller, Chairman, College of Agriculture, UNR, Reno, NV 89557–0004, 702-784-6611.

The University of Nevada Reno is an equal opportunity employer.

Northwestern University/Department of Geological Sciences. Applications are invited for a tenure track position at the assistant professor level from persons who will complement one of the existing departmental research programs in structual geology, tectonics, petrology, or sedimentary geology. Applicants must have a Ph.D. degree by the time of appointment and demonstrate excellence in or strong potential for independent research in one of these fields. In addition to having a strong research orientation the position will involve teaching at the undergraduate and graduate levels and the supervision of graduate student research. Current departmental facilities include VAX 11/750 computer, fully automated JEOL 733 Microprobe/SEM and high pressure and geochemical laboratories.

Letters of application should be accompanied by a resume that includes a description of research interests and accomplishments and teaching experience, a list of publications, and the names of at least three references. Send to: S.O. Schlanger, Chairman, Department of Geological Sciences, Northwestern University, Evanston, Illinois 60201. Closing date for applications is November 1st, 1984. We expect to fill the position for the fall of 1985.

Northwestern University is an equal opportunity/affirmative action employer.

Geophysicist/University of North Carolina. The Department of Geology invites applications for a tenure track faculty position in solid-earth geophysics beginning July 1, 1985. The position probably will be at the assistant professor level, but candidates at the associate professor level will be considered. The Ph.D. is required, and post-doctoral experience is desired. Our preference is for a seismologist and/or tectonophysicist, who would complement current departmental activities, but any good applicant in geophysics will be considered.

Faculty members are expected to conduct a visible and active research program, teach graduate and undergraduate students, and supervise theses.

Inquiries and letters of application should be sent to P. Geoffrey Feiss, Department of Geology 029A, University of North Carolina, Chapel Hill, NC 27514. Applications must include resume, statement of research and teaching interests, and the names of at least three references. Closing date for applications is October 19, 1984.

UNC is an affirmative action/equal opportunity employer.

Senior Level Hydrogeologist. *Requirements:* M.S. + 5 years experience as Project Manager. Computer modeling and writing skills imperative. Strong background in applied hydrogeology integrated with chemistry and engineering desirable.

Remuneration: Commensurate with experience plus excellent benefits and growth potential.

Respond: In confidence stating interest, full resume, references and salary history to Mrs. V.L. Borzos, R.E. Wright Associates, Inc., 5340 Schoolhouse Road, Middletown, PA 17057.

Physical Oceanographers. The Physical Oceanography Branch of the U.S. Naval Oceanographic Office seeks full-time Oceanographers for the study of the effects of oceanic current and thermal/density structure on undersea systems using data collected from various platforms for a variety of projects. The projects involve the collection, analysis and reporting of physical oceanographic data directly applicable to relevant Navy environmental requirements. Up to 50% field duty may be required.

Multiple vacancies at the GS-7, 9 and 11 levels are available depending upon qualifications and experience and will remain open until filled. Salary range: $17,221 to $33,139.

Please contact (for required forms): Debra Staples, #N00–72(84), Commercial 601-688-5700, Autovon 485-5720, or FTS 494- 5720, U.S. Naval Oceanographic Office, Management & Personnel Division, Personnel Operations Branch, Code 4320, Bay St. Louis, NSTL, Mississippi 39522.

Postdoctoral Research Position/Petrology-Geochemistry Northern Illinois University, Department of Geology. Recent Ph.D. recipient is sought for one year position starting in early 1985. Strong analytical background in XRF or plasma spectrometry is preferred. The Department of Geology is in the process of acquiring new, automated XRF and DC plasma spectrometers. The successful candidate will be involved in the development of sample-preparation, analytical, and data-reduction procedures, as well as instruction of other users. Independent or collaborative research will be expected. The Department also has solid- and gas-source mass spectrometers, automated EMP, and excellent computing facilities. Please send application, resume, and the names of three references to J.H. Berg, Departme of Geology, Northern Illinois University, DeKalb, IL 60115. Application deadline is October 15, 1984.

Northern Illinois University is an affirmative action/equal opportunity employer.

American Museum of Natural History. The Department of Mineral Sciences is seeking to fill a tenure track position for Assistant Curator beginning July 1985. This is mainly a research position, but some time is needed for collections management and departmental activities. High quality sample oriented research and publication is the prime responsibility. The field of specialization is mineralogy, broadly defined, and may include and combine aspects of petrologic mineralogy, ore mineralogy, mineral geochemistry, crystal and thermochemistry, mineral physics, X-ray crystallography, ultrastructure analysis, crystal growth, spectroscopy or gemology. Major research facilities include a fully automated ARL/SEMQ electron microprobe, X-ray laboratory, minicomputer, and vast mineral and other collections. The opportunity exists for research and/or teaching collaboration with nearby institutions such as Columbia (Lamont-Doherty Geological Observatory).

Requirements are a Ph.D. in hand by the time of appointment and an ability to carry out a research program. It is expected that some research support will be sought outside the Museum. Applications should include: (1) a curriculum vitae, (2) names of three persons familiar with your work, and (3) a statement of research interests and specific projects to be carried out within the next five years.

These must be submitted by November 15, 1984 to:

Martin Prinz
Chairman, Search Committee
Department of Mineral Sciences
American Museum of Natural History
New York, NY 10024

An equal opportunity (M/F/H) affirmative action employer.

Structural Geologist/Ohio State University. The Department of Geology and Mineralogy of Ohio State University invites applications for a tenure track position for a structural geologist with significant field experience, a strong theoretical background, interests in regional tectonics, and familiarity with seismic interpretation. The successful applicant will be expected to participate in the undergraduate program including field courses, teach graduate courses in his/her field of expertise, supervise graduate students, conduct research, and interact with other department programs in regional geology and geophysics. Consideration will be given to candidates with industrial experience. A Ph.D. degree is required. Rank will be either assistant or associate professor and rank and salary will be commensurate with experience and research record. Please send applications to:

Chairman
Structural Geology Search Committee
Department of Geology and Mineralogy
The Ohio State University
Columbus, OH 43210.

Applications should include a resume and a statement of research interests. Applicants should arrange to have at least three confidential letters of recommendation sent to the committee. The closing date for applications is December 1, 1984; appointments will be effective October 1, 1985.

The Ohio State University is an equal opportunity/affirmative action employer.

Hydrogeologist/Texas A&M University. The Department of Geology and Center for Engineering Geosciences have a tenure track opening, preferably assistant professor level, for which the first search will be for a creative individual working in applied geological hydrology.

The successful applicant will be expected to develop teaching and research recognition at a national level. The position is available beginning September 1, 1984 and will be held open until filled. Applicants should submit a vita including names of references to M.C. Gilbert, Department of Geology, Texas A&M University, College Station, TX 77843.

Texas A&M University is an affirmative action/equal opportunity employer.

Academic Administrator/Assistant or Associate Research Oceanographer. The Center for Coastal Studies, Scripps Institution of Oceanography has an opening for a split-position: 50% Academic Administrator/50% Assistant/Associate Research Oceanographer.

The Center conducts a wide variety of field, laboratory and theoretical work in waves, currents, shore processes, mechanics of nearshore sediment transport, estuarine processes, continental shelf and marginal sea research.

The successful candidate will have a Ph.D in physical oceanography or coastal sciences. The level of appointment will be determined by experience and level of independence in his/her field as evidenced by reviewed publication record in the scientific literature and research record. The ability and desire for interaction with a variety of people within and outside the University, particularly funding agencies, are essential. Knowledge of a broad spectrum of research areas is also essential. Some understanding of administrative issues, e.e. personnel and budgets, is essential.

The Administrator portion of the position is permanently state-funded. The Research portion will be funded by the Center for 12–18 months to enable the candidate to later obtain contract/grant funding either separately or in cooperation with other department researchers.

Send resumes, including areas of research interest and list of publications, with three letters of reference by 31 October 1984 to:

Dr. Douglas L. Inman, Director
Center for Coastal Studies, A-009
Scripps Institution of Oceanography
University of California-San Diego
La Jolla, CA 92093.

UCSD is an Equal Opportunity/Affirmative Action Employer.

Seismologist/Ohio State University. The Department of Geology and Mineralogy, The Ohio State University, invites applications for a tenure-track position for a seismologist with research interests in crustal geology and tectonics. The successful applicant must be prepared to assist in teaching exploration geophysics courses, advanced topics in his/her specialty, conduct research, and supervise graduate students. Postdoctoral or industrial experience is desirable. Rank and salary commensurate with experience and research record. Please send applications or nominations to:

Dr. Ralph R.B. von Frese
Chairman, Search Committee
Department of Geology and Mineralogy
The Ohio State University
Columbus, OH 43210.
Telephone: 614-422-5635 or 422-7921.

Applications should include a resume, a statement of research interests and three persons whom we may contact for recommendations. The closing date for applications is December 1, 1984; appointments will be effective no later than October 1, 1985. Additional information can be obtained by writing or calling the chairman of the search committee.

The Ohio State University is an equal opportunity/affirmative action employer.

The University of Kansas/Faculty Positions. The University of Kansas, Department of Geology seeks to fill three tenure track positions at the Assistant Professor level to begin in Fall, 1985. The Department seeks persons committed to academic excellence involving teaching, research, and service. Salaries will be determined by qualifications and experience and will be competitive. Candidates should hold the Ph.D. degree in Geological Sciences or have it near completion.

All positions carry responsibility for teaching at both undergraduate and graduate level, conducting active programs of research and publication, and supervising the research of students. Candidates should expect to teach introductory courses as well as in their specialties. The Department may give preference to those who are qualified physically and by training or experience to teach in our summer field programs and have the capability to use the computer to solve geological problems.

Position 1. Sedimentation, with interests in the interface between sedimentary processes and stratigraphy, diagenesis and low-temperature geochemistry, or tectonics. Duties will include teaching courses in stratigraphy, sedimentation, sedimentary geochemistry, or tectonics.

Position 2. Tectonics, with interest in the interface between tectonic processes and sedimentation, igneous phenomena, or metamorphism. Duties will include teaching courses in structual geology and tectonics or petrology. Candidates with field orientation will be preferred.

Position 3. Geophysics, with interests in seismology, crustal structure, or potential fields. Candidates should expect to interact with a strong group in the Kansas State Geological Survey and coordinate the academic aspects of the program in geophysics. Duties will include teaching courses in geophysics, crustal structure, or tectonics.

Applicants should send a resume, academic transcripts, and at least three letters of recommendation to: M.E. Bickford, Chairman of Search Committee, Department of Geology, University of Kansas, Lawrence, Kansas 66045-2124. Application materials must be received by 5:00 p.m. November 19, 1984. The positions are contingent upon availability of funds.

The University of Kansas is an AA/EEO employer and encourages applications from all qualified persons.

Project Associate/Specialist: Electron Micro-Probe Lab, University of Wisconsin-Madison. Strong analytical background in quantitative EMP analysis and familiarity with computers is required. The Lab has a 9-spectrometer ARL SEMQ and a JEOLCO 50-A SEM. Duties will include instrument maintenance, instruction of students, development of procedures and analysis. Research will be encouraged. A MS or PhD is required in Earth Science, Chemistry, Physics or Engineering. Minimum salary will be $18,000/12 months with an MS. Send letter of application, transcripts, resume, and names and addresses of three references by September 15 to Dr. John W. Valley, Department of Geology & Geophysics, Weeks Hall, University of Wisconsin, Madison, WI 53706.

An equal opportunity employer.

University of Texas at Austin. The Department of Geological Sciences seeks to fill tenure track positions effective fall 1985 in one or more of the following disciplines: 1) micropaleontology-Tertiary biostratigraphy, 2) structure-tectonics, 3) hydrogeology, and 4) mineralogy-kinetics. Each person is expected to teach both undergraduate and graduate courses and to conduct a vigorous research program, including the supervision of graduate students, in the area of his or her speciality. The positions require the Ph.D. degree. Applicants should submit a detailed resume, names and addresses of five references, a statement of teaching and research interests, and a copy of their dissertation abstract by December 1, 1984 to: Dr. William L. Fisher, Department of Geological Sciences, the University of Texas at Austin, Austin, Texas 78713–7909.

The University is an equal opportunity/affirmative action employer.

Executive Director. Executive Director of newly established Incorporated Research Institutions for Seismology (IRIS), a non-profit consortium of about 40 research universities. Initial duties include setting up Washington, D.C. office with associated financial and clerical services, conducting necessary contract negotiations with federal agencies and private organizations, handling procedures and arrangements for extensive committee activities, and working with the managers of the various research programs. Under supervision of the President, represents the corporation as necessary in dealing with member institutions, funding agencies and contractors in administering large scientific programs. The corporation anticipates a level of research exceeding $20 million annually in five years, with a permanent office staff of up to ten. Candidates must be able to work independently, with little staff support in the first year, and have sufficient breadth and experience to establish an efficient, functioning corporate office. Applicants should submit resumes and names of at least three references to: IRIS, Inc., Department ED, 2000 Florida Avenue, N.W., Washington, D.C. 20009.

IRIS is an equal opportunity employer.

Extension Specialist-Biometeorology. University of Arizona, Tucson, is seeking Biometeorologist, continuing appointment eligible, at Assistant or Associate Specialist level. Incumbent will plan, establish network of weather stations throughout the state, supervise maintenance and render data suitable for client use. Will be Extension source for information on effects of weather on agricultural production.

A PhD in agricultural or forest meteorology, biometeorology or closely related meteorological/climatological area is required, as well as knowledge of computer technology, data acquisition/processing, information dissemination; communication skills; ability to conduct statewide programs in the field.

Applicant's file will contain letter of intent and vita by 12–10–84, plus transcripts of grades and three current reference letters by 1–10–86. All materials must be sent to: Donna Powers, Management Services Officer, Cooperative Extension Service, College of Agriculture, University of Arizona, Tucson, AZ 85721

EEO/AA EMPLOYER.

POSITIONS WANTED

Geologist/Geochemist. 33, M.A., Ph.D. 1983. Specializing in low temperature geochemistry and geochronology with extensive experience in Rb-Sr mass spectrometry. Several publications. Seeks industry, academic research, or government position. Box 027, American Geophysical Union, 2000 Florida Avenue N.W., Washington, DC 20009.

Meetings

Announcements

Water Resources

Oct. 1–4, 1984 5th International Conference on Water Resources Planning and Management, Athens, Greece. Sponsor: European Mediterranean Commission for Water Planning, Hellenic Republic Ministry of Research and Technology. (Conference Secretariat, Th. Xanthopoulos, Division of Water Resources, National Technical University of Athens, 5, Zografou St., GR-157 73 Zografou, Athens, Greece.

Among the topics to be covered are undersea springs and small coastal basins; island applied hydrology; evaluating and forecasting floods and droughts; water development in arid zones; and forecasting hydrological phenomena in real time.

Thermosphere Dynamics

October 3–5, 1984 Goddard Workshop on Thermosphere Dynamics II, Calverton, Md. Sponsor: NASA Goddard Space Flight Center. (Aleta E. Johnson, Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, MD 20771.)

The meeting will assess current understanding of thermosphere dynamics and identify new directions for scientific research in that specialty. The emphasis of the workshop will be on describing the structure and dynamics of the neutral thermosphere, and data recently obtained from the Dynamics Explorer spacecraft and new measurements from ground-based facilities will be considered. Among the topics to be discussed are thermospheric energization processes, long term variations and superrotation, gravity waves, mesosphere-thermosphere coupling, and planetary thermospheres.

Front Range Branch Yellowstone Geology

October 25, 1984 AGU Front Range Branch Symposium on Geophysics and Geology of Yellowstone, Golden, Colorado. Sponsors: AGU Front Range Branch, USGS, Cooperative Institute for Research in Environmental Sciences, U.S. Park Service, Colorado School of Mines. (Jo Ann Joselyn, AGU Front Range Branch, NOAA/SESC, R/E/SE2, 325 Broadway, Boulder, CO 80303; tel.: 303-497-5147.)

The deadline for submission of (one paragraph) abstracts is October 12, 1984.

This symposium, open free of charge to the public, will feature invited talks as well as poster sessions. Outstanding scientists in a variety of geophysical disciplines will present results of their studies in the Yellowstone area. In addition, interested parties are encouraged to submit abstracts of papers to be presented in two poster sessions. Topics will include geochemistry of trace elements within the Yellowstone area's groundwater, hydrologic analysis of the groundwater system, seismotectonics of the Yellowstone area, measurements of tilt in the area and its tectonic interpretation, electrical studies in the Yellowstone area, volcanological studies of the region, and heat flow in the Yellowstone area.

Groundwater Contamination

Nov. 11–16, 1984 Engineering Foundation Conference on Groundwater Contamination, Santa Barbara, Calif. Sponsors: The Engineering Foundation, Universities Council on Water Resources. (Engineering Foundation, 345 E. 47th St., New York, NY 10017; tel.: 212-705-7835.)

Groundwater contamination continues to present problems and concerns to water users and management agencies at all levels. Solutions to contamination problems require a wide range of knowledge cutting across many disciplines and sciences. This conference aims to identify critical groundwater contamination issues and develop feasible approaches to providing solutions. The conference also will identify possible barriers to implementation of solutions and develop alternative approaches for solving groundwater contamination problems.

Topics to be presented include sources, reasons, and impacts of groundwater contamination; groundwater hydrology; case studies; institutional, legal, and economic aspects of groundwater contamination; prevention; physical and nonstructural solutions; the role of local, state, and federal government in prevention; and identification of disciplinary, interdisciplinary, and multidisciplinary research needs.

Quaternary Climatic Change

April 14–19, 1985 GSA Penrose Conference on Geomorphic and Stratigraphic Indicators of Neogene-Quaternary Climatic Change in Arid and Semiarid Environments, Lake Havasu City, Ariz. Conveners: John Dohrenwend, USGS; Steve Wells and Les McFadden, University of New Mexico. (John Dohrenwend, U.S. Geological Survey, MS 941, 345 Middlefield Rd., Menlo Park, CA 94025.)

Those interested in attending should notify the convenors before November 30, 1984. Most of the conference will be devoted to discussions, but those interested in presenting an oral paper or poster should submit a title and summary (of abstract length) by November 15, 1984.

The conference will examine the impact of climatic change on landscape degradation and associated alluvial, eolian, and lacustrine deposition in arid and semiarid environments. Recent advances in relative and "absolute" dating techniques, Quaternary paleoclimatology, and continental sedimentology will be examined to establish an overall framework for discussion of models of landscape evolution and for evaluation of geomorphic and stratigraphic indicators of climate change. Scientists from a wide variety of disciplines are invited to attend, including paleoclimatology, paleobotany, sedimentology, geomorphology, and radiometric dating.

Soil Dynamics and Earthquakes

June, 1985 Second International Conference on Soil Dynamics and Earthquake Engineering, on board the Queen Elizabeth II. Sponsor: Computational Mechanics Institute. (C. A. Brebbia, Computational Mechanics Institute, Ashurst Lodge, Ashurst, Southampton SO4 2AA England.)

Deadline for abstracts (of no more than 300 words) is November 1, 1984.

The conference will provide a forum for the presentation and discussion of new and advanced ideas in soil dynamics and earthquake engineering. Conference themes include geotechnical earthquake engineering; engineering seismology; seismic waves in soils and geophysical methods; experimental soil dynamics; liquefaction of soils; dynamic earth pressures and design of earth retaining structures; earthquake geotechnology in offshore problems; earthquake behavior of fluid container facilities; and case histories in geotechnical earthquake engineering.

Karst Water Resources

July 7–19, 1985 International Symposium on Karst Water Resources, Ankara and Antalya, Turkey. Sponsors: Karst Water Resources Research Center Project of Hacettepe Univ., U.N., Turkish State Hydraulic Works. (A. Ivan Johnson, Water Resources Consultant, Woodward-Clyde Consultants, 7600 East Orchard Rd., Harlequin Plaza North, Englewood, CO 80111, or Gultekin Gunay, Hydrogeological Engineering Dept., Hacettepe Univ., Engineering Faculty, Beytepe, Ankara, Turkey.)

Notice of intent to offer a paper or attend the symposium should be sent to either of the contacts, Johnson or Gunay, as soon as possible.

Because of the unique problems associated with water resources development and construction in karstic areas, this symposium is organized to bring together international interdisciplinary specialists in karst. Turkey provides an appropriate location because of the quantity, variety, and importance of the karstic areas there. Among the subjects that may be considered for the symposium are hydrogeology, geochemistry, modeling, laboratory testing, tracer techniques, geophysics, other exploratory methods, land subsidence and sinkhole formation, remote sensing techniques, groundwater and surface-water hydraulics and interpretation, engineering properties and problems, water-supply esti-

Meetings (cont. on p. 712)

Meetings *(cont. from p. 711)*

mation, irrigation potential, and irrigation practice.

IAGA Assembly

August 5–17, 1985 5th Scientific Assembly of the International Association of Geomagnetism and Aeronomy (IAGA), Prague, Czechoslovakia. (Michael Gadsden, Natural Philosophy Dept., Aberdeen Univ., Aberdeen AB9 2UE, Scotland.)

The assembly will include a full program of scientific sessions involving all the following IAGA Divisions and Commissions together with two Commissions of the International Association of Meteorology and Atmospheric Physics (IAMAP): Solid Earth Geomagnetism; Aeronomy; Magnetosphere; Solar Wind; Observatories and Indices; Antarctic; History; Middle Atmosphere; Internal/External Geomagnetism; Developing Countries; Meteorology of the Upper Atmosphere; and Radiation.

IAGA Working Group 1–5 (Paleomagnetism) has arranged for a full day session on "Analytical Methods for Paleomagnetism" on August 12. Among the possible topics for discussion are methods of generating APW paths from paleomagnetic data, methods of using APW paths to determine relative positions of plates, methods of handling temporal data such as those from sediment cores, and special problems involving archaeomagnetic data. Those who wish to present papers at this session are asked to contact C. G. A. Harrison, School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Cswy, Miami, FL 33149.

Future AGU Meetings

Fall Meetings

- Dec. 3–7, 1984, San Francisco, California.Abstracts due September 12, 1984; call for papers appeared in July 3, 1984 *Eos*.
- Dec. 9–13, 1985, San Francisco, California. Abstracts due mid-September 1985.
- Dec. 8–12, 1986, San Francisco, California.

Spring Meetings

- May 27–31, 1985, Baltimore, Maryland. Abstracts due early March 1985.
- May 19–23, 1986, Baltimore, Maryland.

Regional Meetings

- Front Range Branch Symposium on Geophysics and Geology of Yellowstone, October 25, 1984, Golden, Colorado. Abstracts due October 12, 1984; call for papers appears in September 18, 1984 *Eos*.
- Front Range Branch Hydrology Days, April 16–18, 1985, Fort Collins, Colorado. Abstracts due December 31, 1984 for professional hydrologists; February 15, 1985 for students; call for papers appeared in July 24, 1984 *Eos*.

Chapman Conferences

- Vertical Crustal Motion: Measurement and Modeling, October 23–26, 1984, Harpers Ferry, West Virginia.
- Solar Wind-Magnetosphere Coupling, February 12–15, 1985, Pasadena, California. Abstracts due November 1, 1984; call for papers appeared in July 10, 1984 *Eos*.
- Ion Acceleration in the Ionosphere and Magnetosphere, June 3–7, 1985, Boston, Massachusetts.
- Magnetotail Physics, October 28–31, 1985, Laurel, Maryland.

The last Geophysical Year calendar ran August 28, 1984, in *Eos*.

Housing and Registration

The 1984 Fall Meeting of the American Geophysical Union and the Winter Meeting of the American Society of Limnology and Oceanography (ASLO) will be held in San Francisco, December 3–7, at the Civic Auditorium.

San Francisco has been host to AGU's annual Fall Meeting for many years. If you have attended previous Fall Meetings, you know what a pleasing city San Francisco can be—fine restaurants, temperate December climate, and the charms of Chinatown, Ghirardelli Square, Fisherman's Wharf, Nob Hill, and North Beach. San Francisco is an elegant city, offering a rich blend of stylish hospitality and hometown amiability. By any measure, San Francisco is an ideal backdrop for this year's scientific sessions.

Registration

Everyone who attends the meeting must register. Preregistration received by November 9 saves you time and money. The fee will be refunded to you if AGU receives written notice of cancellation by November 30. Registration rates are as follows:

	Preregistration	After November 9
Member (AGU/ASLO)	$70	$85
Student Member (AGU)	$30	$45
Retired Senior Member* (AGU/ASLO)	$30	$45
Nonmember	$95	$110
Student Nonmember	$40	$55

*Age 65 or over and retired from full-time employment.

Registration for 1 day is available at one half the above rates, either in advance or at the meeting. Members of the American Congress on Surveying and Mapping, the American Meteorological Society, the American Society of Photogrammetry, the Canadian Geophysical Union, the European Geophysical Union, and the Union Geofísica Mexicana may register at the AGU/ASLO member rates.

If you are not a member of AGU and you register at the full nonmember meeting rate, the difference between member (or student member) registration and nonmember registration will be applied to 1985 AGU dues if a completed membership application is received at AGU by February 28, 1985.

To preregister, fill out the registration form and return it with your payment to AGU by November 9. Preregistrants should pick up their registration material at the registration desk located at the Civic Auditorium in the Main Arena. Your receipt will be included with your preregistration material. Registration hours are 7:45 A.M. to 4:30 P.M., Monday through Friday. On Sunday, December 2, registration will be held at the Cathedral Hill Hotel. You may register from 4:00 P.M. to 8:00 P.M.

Hotel Accommodations

Blocks of sleeping rooms are being held at the following hotels:

- Cathedral Hill Hotel ($51 single/$55 double)
  Free parking to registered guests
  Limited shuttle service to and from the Civic Auditorium
  Airport shuttle service available
  Coffee shop opens 6:30 A.M.
- Holiday Inn Golden Gateway ($49 single/$55 double)
  Free parking to registered guests
  Limited shuttle service to and from the Civic Auditorium
  Airport shuttle service available
  Coffee shop opens 6:30 A.M.
- The Grosvenor Inn ($49 single/$55 double)
  Limited shuttle service to and from the Civic Auditorium
  Airport shuttle service available
  Coffee shop opens 7:00 A.M.
- The Holiday Inn Civic Center ($49 single/$55 double)
  Two blocks away from the Civic Auditorium
  Free parking to registered guests
  Airport shuttle service available
  Coffee shop opens 6:30 A.M.
- The San Francisan Hotel ($50 single/$56 double)
  One block away from the Civic Auditorium
  Airport shuttle service available
  Parking $3 a day to registered guests
  Coffee shop opens 6:30 A.M.
- Carriage Inn Hotel ($52 single/$54 double)
  Victorian style inn
  Free parking to registered guests
  Walking distance to the Civic Auditorium
  Shuttle service available to airport
  Free continental breakfast and newspaper
- Americania Hotel ($49 single/$54 double)
  Free parking to registered guests
  Walking distance to the Civic Auditorium
  Shuttle service available to airport
  Free coffee served in sleeping rooms
- Flamingo Motor Inn ($43 single/$43 double)
  Free parking to registered guests
  Walking distance to the Civic Auditorium
  Shuttle service available to airport
- Hotel Britton ($35 single/$38 double)
  Inexpensive parking available to registered guests
  Walking distance to the Civic Auditorium
  Coffee shop opens 7:00 A.M.
  Shared baths

The Cathedral Hill, Holiday Inn Golden Gateway, and the Grosvenor hotels are approximately a mile away from the Civic Auditorium. Limited shuttle bus service will be provided from these hotels to the Civic Auditorium for those who do not want to walk.

Read the housing application and mail the completed application form to the housing bureau early to ensure reservations at your preferred hotel. Reservation forms must be sent directly to the Housing Coordinator, AGU Fall Meeting, San Francisco Housing Bureau, P.O. Box 5612, San Francisco, CA 94101. Do not send housing reservation forms to the hotel.

Reservations must be received by October 31 to be confirmed. Do not write or call AGU for room reservations.

Scientific Sessions

The program summary will be published in the October 16 issue of *Eos*. The preliminary program with the abstracts will be published in the November 6 issue of *Eos*. The final meeting program, with presentation times, will be distributed at the meeting. All scientific sessions will be held at the Civic Auditorium.

Exhibits

Exhibits of instrumentation equipment, book publishers, program of government agencies, and other exhibits will be located at the Civic Auditorium in the Main Arena. The exhibits will be open Tuesday, December 4, through Thursday, December 6, 9:00 A.M. to 5:00 P.M. daily.

The following exhibitors are confirmed to date:

Academic Press
American Congress on Surveying and Mapping
American Society of Limnology and Oceanography
Earth Data Limited
Elsevier Science Publishing Company, Inc.
Jet Propulsion Laboratory/TOPEX Project
Kinemetrics, Inc.
Kluwer Academic Publishers (D. Reidel)
National Science Foundation
Nature's Own
Pacific Delight
Qualimetrics, Inc./Weathertronics
Schonstedt Instrument Company
Sea-Bird Electronics, Inc.
Sprengnether Instruments
Springer-Verlag, New York Office
Teledyne Geotech
Terra Technology Corporation
U.S. Geological Survey

Social Functions

All meeting participants are invited to attend these events:

- Icebreaker party
  Monday, 6:00–7:30 P.M.
  Holiday Inn Golden Gateway
- Wine Reception
  Thursday, 6:00–7:30 P.M.
  Cathedral Hill Hotel
- Complimentary refreshments will be served daily at the Civic Auditorium

Business Meetings and Section Luncheons

The AGU Council will meet Tuesday, December 4, at 5:30 P.M., at the Cathedral Hill Hotel. Members are welcome to attend.

ASLO will hold a no-host smoker (cash bar), Tuesday, December 4, at 5:30 P.M., at the Cathedral Hill Hotel

The section luncheons will be held at the San Francisan (SF) and Holiday Inn-Civic Center (HICC) hotels. Please indicate on the registration form which luncheon you plan to attend and include payment.

AGU Council Meeting
Tuesday, December 4, 5:30 P.M.
Cathedral Hill Hotel

ASLO No-Host Smoker
Tuesday, December 4, 5:30 P.M.
Cathedral Hill Hotel

Tuesday, December 4, Noon
Geomagnetism and Paleomagnetism (HICC), $11.50
Planetology/Volcanology, Geochemistry, and Petrology (SF), $11.50
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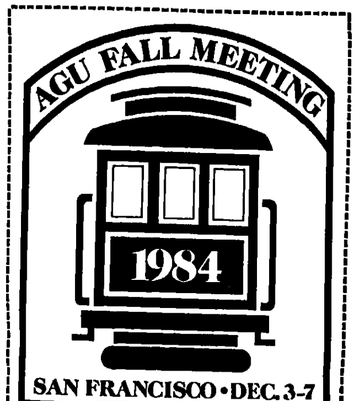

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Exploration Geophysics

0920 Magnetic and electrical methods
COMPUTATION OF GREEN'S TENSOR INTEGRALS FOR THREE-DIMENSIONAL ELECTROMAGNETIC PROBLEMS USING FAST HANKEL TRANSFORMS
Walter L. Anderson (U.S. Geological Survey, Box 25046, MS 964, Denver Federal Center, Denver, CO 80225)

A new method is presented that rapidly evaluates the many Green's tensor intergrals encountered in three-dimensional electromagnetic modeling using an integral equation. Application of a fast Hankel transform (FHT) algorithm (Anderson, 1982) is the basis for the new solution, where efficient and accurate computation of Hankel transforms are obtained by related and lagged convolutions (linear digital filtering). The FHT algorithm is briefly reviewed and compared to earlier convolution algorithms written by the author. The homogeneous and layered half-space cases for the Green's tensor integrals are presented in a form so that the FHT can be easily applied in practice. Computer timing runs comparing the FHT to conventional direct convolution methods are discussed, where the FHT's performance was about 6 times faster for a homogeneous half-space, and about 108 times faster for a five-layer half-space.

Subsequent interpolation after the FHT is called is required to compute specific values of the tensor integrals at selected transform arguments; however, due to the relatively small lagged convolution interval used (same as the digital filter's), a simple and fast interpolation is sufficient (e.g., by cubic splines).
GEOPHYSICS, VOL. 49, NO. 10

0920 Magnetic and electrical methods
TWO-DIMENSIONAL RESISTIVITY INVERSION
A.C. Tripp (Formerly University of Utah, Salt Lake City, UT; presently ARCO Oil and Gas Co., P.O. Box 2819, Dallas, TX 75221) G.W. Hohmann, and C.M. Swift, Jr.

Resistivity data on a profile often must be interpreted in terms of a complex two-dimensional (2-D) model. However, trial-and-error modeling for such a case can be very difficult and frustrating. To make interpretation easier and more objective, we have developed a nonlinear inversion technique that estimates the resistivities of cells in a 2-D model of predetermined geometry, based on dipole-dipole resistivity data.

Our numerical solution for the forward problem is based on the transmission-surface analogy. The partial derivatives of apparent resistivity with respect to model resistivities are equal to a simple function of the currents excited in the transmission surface by transmitters placed at receiver and transmitter sites. Thus, for the dipole-dipole array the inversion requires only one forward problem per iteration. We use the Box-Kanemasu method to stabilize the parameter step at each iteration.

We have tested our inversion technique on synthetic and field data. In both cases, convergence is rapid and the method is practical if the number of parameters is not too large. The main limitations of the method are that the geometry of the model must be specified in advance, and that it is difficult to determine whether model misfit is due to 3-D effects or to underparameterization in the 2-D model. The technique should be used interactively, with models constrained by geologic information.
GEOPHYSICS, VOL. 49, NO. 10

0920 Magnetic and electrical methods
MAGNETOTELLURIC MEASUREMENTS ACROSS THE EASTERN NEOVOLCANIC ZONE IN SOUTH ICELAND
H. Eysteinsson (Department of Geological Sciences, Brown University, Providence, RI 02912) J. F. Hermance

A magnetotelluric (MT) survey consisting of 18 separate soundings was performed in 1982 along a 125 km profile crossing the eastern neovolcanic zone in south Iceland. Although the 3-D ocean effect may be significant at the longest periods which previous workers have analysed to study features in the upper mantle beneath Iceland, our studies suggest that this effect is minimal for periods less than 1000 s at distances greater than 50 km from the coast. Therefore, we are confident that 2-D interpretations are valid at periods suitable for interpreting crustal resistivities. Such a 2-D interpretation presented here indicates the presence of a layer (~5 km thick) of low resistivity (5 ohm-m) at the crust-mantle interface (10–20 km depth). The depth to this layer increases from the center of the neovolcanic zone. This feature has been seen elsewhere in Iceland by other workers. However the present study suggests that east of the neovolcanic zone the low resistivity layer is not present, which we argue may be associated with a recent eastward shift of the axial rift zone to a new location within older crust. A striking feature of our 2-D crustal interpretation is that pockets of low resistivity material appear to be present at approximately 8 km depth at the base of the crust beneath the two volcanic centers that we have studied, Torfajokull and Hekla. These may be manifestations of local magma chambers.

J. Geophys. Res., B, Paper 4B1152.

0920 Magnetic and electrical methods
THE INFLUENCE OF PORE GEOMETRY ON THE DIELECTRIC DISPERSION OF CLEAN SANDSTONES
J. Korringa (Chevron Oil Field Research Company, P.O. Box 446, La Habra, CA 90631)

In an idealized description a clean sandstone is an isotropic two-component medium consisting of a solid with dielectric constant ϵ_s and a pore fluid (brine) with dielectric constant ϵ_f and conductivity σ_f. On the basis of D. Bergman's work [Annals of Physics 138, 78, 1982] the dielectric response of such a medium is expressed in terms of the dc conductivity and of a real, positive and bounded function, defined in (1, 0) and independent of ϵ_s, ϵ_f, and σ_f. This function is restricted by three relations which express weighted averages of it in terms of the asymptotic value of the dielectric response at high frequency, the porosity, and the dc conductivity.

The formalism is exact for two-component media of the type specified. It supplements an approximate treatment by Lysne (1983) and can, without much difficulty, be generalized to any isotropic two-component composites.
GEOPHYSICS, VOL. 49, NO. 10

0920 Magnetic and electrical methods
AN INTERPRETIVE ANALYSIS OF MAGNETOTELLURIC DATA
R.P. Ranaganayaki (Mobil Research and Development Corporation, Dallas Research Division, P.O. Box 819047, Dallas, TX 75381)

A simple analysis to determine the dimensionality of magnetotelluric resistivity variations, to separate the near-surface resistivity variation from the variations at depth, and to find the relative resistivity variations with depth is described. Parameters derived from the magnetotelluric impedance tensor are mapped in pseudo-section and planar view for two-dimensional (2-D) model data and for survey data from Montana. These data illustrate procedures that can qualitatively map complex resistivity structures in the lateral distance-frequency domain or, equivalently, the lateral distance-scaled vertical distance domain. Phase-dependent parameters have better vertical resolution than parameters related to scalar apparent resistivity, but the latter allow estimates of the resistivities encountered. Phase parameters for the Montana data provide a semiquantitatively accurate cross-section of a geologically known anticlinal structure. This suggests a means of subsurface structural mapping with magnetotelluric data. The use of these parameters with sufficiently dense and accurate data provides a first-order indication of structure for subsequent quantitative modeling.
GEOPHYSICS, VOL. 49, NO. 10

0920 Magnetic and electrical methods
SOLUTION OF THE FUNDAMENTAL PROBLEM IN RESISTIVITY LOGGING WITH A HYBRID METHOD
Leung Tsang (Formerly Electrical Engineering Dept., Texas A&M University; presently Dept. of Electrical Engineering, University of Washington, Seattle, WA 98195) Andrew K. Chan, and Stanley Gianzero

The fundamental resistivity logging problem of a resistivity tool in the presence of both vertical and horizontal boundaries is solved with a hybrid method. The hybrid method combines the mode concept in wave-guide theory together with the finite-element method. In the mathematical formulation, the horizontal boundaries are used to separate the geometry of the problem into different regions. In each region, the waveguide modes are obtained through the solution of an equivalent variational problem. The solutions are calculated by a one-dimensional finite-element method. The vertical boundaries are taken into account in these calculations. The orthonormality of modes in each region allows a series representation of the potential in the regions. Boundary conditions at horizontal bed boundaries then couple the modes between different regions and enable the solutions for the potential to be expressed in terms of reflection and transmission matrices of modes. The source excitation determines the amplitudes of the modes.

The results of the hybrid method are in excellent agreement with those of the integral transform solution. Numerical results of the apparent resistivity are illustrated as a function of formation properties. The effects of an invaded zone are also examined by considering radial inhomogeneous profiles in the formation.

The results of the hybrid method are numerically efficient because it reduces the two-dimensional finite-element problem into a one-dimensional one. It also provides a physical interpretation of the solution in terms of modes.
GEOPHYSICS, VOL. 49, NO. 10

0910 Seismic methods
ROOT-MEAN-SQUARE VELOCITIES AND RECOVERY OF THE ACOUSTIC IMPEDANCE
D.W. Oldenburg (University of British Columbia, 2075 Westbrook Mall, Vancouver, B.C., Canada V6T 1W5) S. Levy and K. Stinson

The loss of low-frequency information in reflection seismograms causes serious difficulties when attempting to generate a full-band impedance profile. Information about the low-frequency velocity structure is available from rms (stacking velocities). We show how rms velocities can be inverted with additional point velocity constraints (if they are available) to construct either smooth or blocky velocity structures. Backus-Gilbert averages of the constructed velocity are then autoregressive solutions for recovering a full band reflectivity from band-limited seismograms. Our final result is therefore a full-band acoustic impedance which is consistent with the seismic data section, stacking velocities, and available point constraints.
GEOPHYSICS, VOL. 49, NO. 10

0930 Seismic methods
PLANE-WAVE REFLECTION COEFFICIENTS FOR GAS SANDS AT NONNORMAL ANGLES OF INCIDENCE
W.J. Ostrander (Chevron U.S.A., Inc., 2003 Diamond Boulevard, Concord, CA 94520)

The *P*-wave reflection coefficient at an interface separating two media is known to vary with angle of incidence. The manner in which it varies is strongly affected by the relative values of Poisson's ratio in the two media. For moderate angles of incidence, the relative change in reflection coefficient is particularly significant when Poisson's ratio differs greatly between the two media.

Theory and laboratory measurements indicate that high-porosity gas sands tend to exhibit abnormally low Poisson's ratios. Embedding these low-velocity gas sands into sediments having "normal" Poisson's ratios should result in an increase in reflected *P*-wave energy with angle of incidence. This phenomenon has been observed on conventional seismic data recorded over known gas sands.
GEOPHYSICS, VOL. 49, NO. 10

0930 Seismic methods
SEISMIC APPROACHES FOR STRUCTURAL STUDIES OF THE SUDBURY BASIN
Derbew Mesfin (Formerly University of Manitoba, Winnipeg, Manitoba, Canada; presently Geological Survey of Ethiopia, Addis Ababa, Ethiopia) Wooil Moon

This study investigates the feasibility of applying seismic techniques in the search for ore deposits, with particular emphasis given to locating orebodies at great depths. The basic procedure followed was essentially an understanding of the forward problem, whereby the effects of the subsurface structure in a typical mining district were thoroughly studied. The initial stage of the study was devoted to determining the elastic parameters by laboratory measurement of seismic velocities and densities of core samples obtained from the Sudbury basin, Canada.

By virtue of its ability to handle lateral as well as vertical inhomogeneities, fast computing time and flexibility, the asymptotic ray theory was judged to be more suitable for studying the effect of geologic structures typically found in the Sudbury basin. Both large-scale and small-scale models, representing actual geologic conditions in Sudbury, were constructed. The computed seismic response of the large-scale models shows that the micropegmatite/oxide-rich quartz gabbro and the mafic norite/granite gneiss contacts are characterized by substantially strong reflections, indicating that these two interfaces can serve as marker horizons in future seismic surveys. In the small-scale models of mineralized structures, the sulfide body was outlined by a distinctly high amplitude of reflection. Both the traveltime and the dynamic characteristics of these models have features that are indicative of the presence of mineralized structures.
GEOPHYSICS, VOL. 49, NO. 10

0930 Seismic methods
CRUSTAL STRUCTURE OF THE CONTINENTAL SHELF OFF NORTHWEST BRITAIN FROM TWO-SHIP SEISMIC EXPERIMENTS
E.J.W. Jones (Department of Geology, University College London, Gower Street, London WC1E 6BT) R.S. White, V.J. Hughes, D.H. Matthews, and B.R. Clayton

Two-ship multichannel seismic profiles, using expanding spread and constant offset source-receiver configurations, were shot with explosive charges and a 16.4 ℓ air gun to investigate the structure of the continental shelf off northwest Britain. A long-range (69 km) expanding spread profile reveals that the crystalline basement off northern Scotland is covered by sedimentary sections up to 2.5 km thick, and is divisible into two seismic units with velocities of 6.1 km/s and 6.6 km/s. Prominent supercritical Moho reflections indicate a crustal thickness of 26.7 km. Strong sedimentary and basement refractions, together with oblique reflections from the vicinity of the Moho, have been profiled at a constant air gun-receiver offset of 10 km across a sedimentary basin west of the Orkney Islands.

On the Outer Hebridean shelf to the west of mainland Scotland, the metamorphic basement lies within 250 m of the sea floor. *P*- to *S*-wave conversion occurs at the basement surface; V_p/V_s gives a Poisson's ratio of 0.27–0.31 at depths of 300–1,000 m. Marked changes in mode conversion efficiency are observed on constant offset profiles and are attributed to variations in the velocity structure of an uppermost low-velocity (4.9 km/s) layer of weathered basement. The deeper crustal velocity appears uniform with depth, although there is some evidence of significant lateral velocity changes (6.28–6.61 km/s). In contrast to the shelf north of Scotland, reflections from within the basement and from near the base of the crust are recorded only sporadically on constant offset profiles. A strong event at 10.4 s two-way reflection time appears to have arisen from a seismic discontinuity within the upper mantle. The difference in seismic character of the basement on the two-ship profiles suggests significant variations in crustal structure within the Caledonian foreland of northern Britain.
GEOPHYSICS, VOL. 49, NO. 10

0930 Seismic methods
MIGRATION VELOCITY ANALYSIS BY WAVE-FIELD EXTRAPOLATION
Oz Yilmaz (Western Geophysical Company, P.O. Box 2469, Houston, TX 77001) Ron Chambers

Velocity information is essential to both common midpoint (CMP) stacking and migration. CMP stacking provides the basis for conventional velocity estimation techniques in that, for a number of trial velocities, the stack response of a CMP gather is computed and displayed in the form of a velocity table. An alternative approach to velocity estimation makes use of the basic ingredients of migration—downward extrapolation and imaging of seismic wave fields. The procedure involves migration of a CMP gather with a number of trial velocities and collection of the zero-offset information, again in the form of a velocity table. Operating on a CMP gather, the migration-based approach produces results similar to those of the conventional method. Analyses of synthetic CMP gathers using both methods show essentially equivalent treatments of seismic signal, and similar dependence of accuracy and resolving power on recording geometry.

We have extended the migration-based approach to include more than one CMP gather in each analysis. This extension allows proper treatment of dipping events and yields velocity information that is more appropriate for use in migration. By using the intermediate wave field at each step of downward extrapolation, we need only do a single constant-velocity migration of the unstacked data followed by a simple mapping procedure in order to recover the velocity information.
GEOPHYSICS, VOL. 49, NO. 10

Geochemistry

1410 Chemistry of the Atmosphere
ATMOSPHERIC METHANE IN THE RECENT AND ANCIENT ATMOSPHERES: CONCENTRATIONS, TRENDS, AND INTERHEMISPHERIC GRADIENT
R.A. Rasmussen and M.A.K. Khalil (Oregon Graduate Center, Beaverton, Oregon 97006).

The concentrations of methane in the old and ancient atmospheres of the earth can be deduced by analyzing the air in bubbles embedded in polar ice cores. Upon analyzing some 80 ice core samples from the polar regions we found that the concentration of methane 250 years ago and earlier was only 700 (±30) ppbv or about 45% of present levels. A rapid and significant increase of atmospheric methane started about 150 years ago. The rate of increase has escalated since then and is about 1.3%/yr at present. We also found that the concentration of methane in the atmosphere 250 years ago and earlier, when methane was not increasing, was 10% (±4%) higher in the arctic compared to the antarctic. This finding is consistent with the expected ratio of about 1.07–1.11 obtained from a global mass balance model and the primarily land-based natural sources of methane estimated to be about 280 Tg/yr, which may have existed several hundred years ago when human activities did not contribute significantly to the global methane cycle. (Pre-industrial levels; atmospheric methane; interhemispheric gradient; polar ice; anthropogenic sources; natural emissions, secular trends.)

J. Geophys. Res., D, Paper 4D0996.

1410 Chemistry of the Atmosphere
PRECIPITATION CHEMISTRY AT TURRIALBA, COSTA RICA
C.D. Hendry (Environmental Science and Engineering, Inc., P.O. Box ESE, Gainesville, Florida, 32602), C.W. Berish, and E.S. Edgerton

Bulk precipitation samples were collected weekly at Turrialba, Costa Rica, from March 1979 through March 1981 and analyzed for pH, conductivity, major cations and anions, nutrient (N and P) species, and 12 trace metals. Results indicated that Costa Rica precipitation contains relatively low levels of acidity, nutrients, and minerals. For example, during the precipitation years 3/79–3/80 and 4/80–4/81, volume-weighted mean specific conductances were 4.89 and 4.82 μS/cm, respectively. Precipitation pH values ranged from 4.81 to 6.35 and the volume-weighted mean pH was 5.34 over the two-year study. Based upon equivalent ratios, excess $[SO_4^{2-}]$ was found to be the principal acidic anion, with only small possible contributions from excess $[Cl^-]$ or NO_3^-. Marine-derived aerosol accounted for virtually all of the Na^+, Mg^{2+}, and Cl^- deposited in Turrialba rain, and was a minor contributor (3–15%) to the K^+, Ca^{2+}, and SO_4^{2-} loadings. Excess $[SO_4^{2-}]$ comprised 85% of the total SO_4^{2-} and may arise in Costa Rican precipitation due to long-range transport, biogenic sources, or local volcanic emissions. Highest concentrations of minerals and nutrients were observed during the low rainfall period of early spring, which coincided with increased agricultural activities. Very low levels of trace metals were observed in the precipitation. (Precipitation chemistry, acid rain, rainfall analysis).

Water Resour. Res., Paper 4W1046.

1440 Chemistry of the solid Earth
RADIOGENIC RARE GASES AND THE EVOLUTIONARY HISTORY OF THE DEPLETED MANTLE
D. E. Fisher (Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida, 33149)

U,Th/He, K/Ar, and U/Xe ages of the depleted mantle source region of oceanic basalts are much less than the age of the earth, showing clearly that the MORB mantle source was not completely degassed and decoupled from the atmosphere early in earth history. Rather, extensive degassing has continued up to at least the last few hundred million years. A stable, layered mantle is not suggested by these data. (Rare gases, MORB, geochronology, mantle).

J. Geophys. Res., B, Paper 4B1132.

1490 Instruments and Techniques (Instrumentation)
AN INTERCOMPARISON OF CARBON MONOXIDE, NITRIC OXIDE AND HYDROXYL MEASUREMENT TECHNIQUES: OVERVIEW OF RESULTS
J. M. Hoell, Jr. (NASA Langley Research Center, Hampton, VA 23665), G. L. Gregory, M. A. Carroll, M. McFarland, B. A. Ridley, D. D. Davis, J. Bradshaw, M. O. Rodgers, A. L. Torres, G. W. Sachse, G. F. Hill, E. P. Condon, R. A. Rasmussen, M. C. Campbell, J. C. Farmer, J. G. Sheppard, C. C. Wang, and L. I. Davis

Results from an intercomparison of methods to measure carbon monoxide (CO), nitric oxide (NO), and the hydroxyl radical (OH) are discussed. The intercomparison was conducted at Wallops Island, VA, in July 1983 and included a laser differential absorption and three grab sample/gas chromatograph methods for CO, a laser induced fluorescence (LIF) and two chemiluminescence methods for NO, and two LIF methods and a radiocarbon tracer method for OH. The intercomparison was conducted as a field measurement program involving ambient measurements of CO (130 to 300 ppbv) and NO (10 to 180 pptv) from a common manifold with controlled injection of CO in incremental steps from 20 to 500 ppbv and NO in steps from 10 to 200 pptv. Only ambient measurements of OH were made. The agreement between the techniques was on the order of 14% for CO and 17% for NO. Hardware difficulties during the OH tests resulted in a data base with insufficient data and uncertainties too large to permit a meaningful intercomparison. (Carbon Monoxide, Nitric Oxide, Hydroxyl, Instrumentation).

J. Geophys. Res., D, Paper 4D1107.

Geodesy and Gravity

1910 Crustal Movements
UPLIFT ACROSS LONG VALLEY CALDERA, CALIFORNIA
R.O. Castle (U.S. Geological Survey, Menlo Park, CA 94025), J.E. Estrem, and J.C. Savage

The results of levelings along U.S. Highway 395 between Lee Vining and Toms Place, California, in 1957, 1975, 1980, 1982, and 1983 define the development of a dome-shaped uplift across the Long Valley caldera. These levelings indicate that Toms Place remained virtually invariant with respect to Lee Vining during the full interval 1957–1983, implying that the end points of the survey route lie beyond the range of the developing dome. No significant uplift occurred before 1975, but by October 1980 the uplift near Casa Diablo Hot Springs reached 0.25 m and the half-width of the dome was of the order of 25 km. The uplift of Casa Diablo Hot Springs increased to 0.35 m by August 1982 and to about 0.40 m by August 1983 without any appreciable increase in the lateral extent of the dome. The August 1982–August 1983 uplift apparently occurred before February 1983 with little or no uplift during the period February–August 1983. The 1975–1983 uplift is attributed to the injection of 0.19 km^3 of magma into a spherical chamber at a depth of 10 km beneath the southern quadrant of the ancient resurgent dome within the caldera. Examination of the full vertical-control record through the Long Valley area indicates that the 1975–1983 uplift is unique within the period 1905–1983. Although comparisons of the results of a 1932 leveling against a 1914 datum disclose a 1914–1932 down-to-the-northwest tilt of about 10 μrad over the reach between Toms Place and Lee Vining, this tilt (if real) is more reasonably attributed to regional tectonic deformation than it is to the movement of magma at depth.

J. Geophys. Res., B, Paper 4B1091.

1930 High-order harmonics of the gravity potential field and local gravity anomalies
AN ATTEMPT TO FORMULATE WELL-POSED QUESTIONS IN GRAVITY: APPLICATION OF LINEAR INVERSE TECHNIQUES TO MINING EXPLORATION
Vincent Richard (Centre Geologique et Geophysique, Univ. des Sciences et Tech. du Languedoc, 34060 Montpellier, Cedex, France) Roger Bayer and Michel Cuer

The aim of this paper is to use linear inverse theory to interpret gravity surveys in mining exploration by incorporating a priori information on the densities and data in terms of Gaussian or uniform probability laws. The Bayesian approach and linear programming techniques lead to the solution of well-posed questions resulting from the exploration process. In particular, we develop a method of measuring the possible heterogeneity within a given domain by using linear programming. These techniques are applied to gravity data taken over the massive sulfide deposit of Neves Corvo (Portugal). We show how crude constraints on the densities lead to a first estimation of the location of sources, while further geologic constraints allow us to estimate the heterogeneity and to put definite bounds on the ore masses.
GEOPHYSICS, VOL. 49, NO. 10

1950 Relations of gravity observations to tectonic and isostasy
THERMO-MECHANICAL EVOLUTION OF OCEANIC FRACTURE ZONES
D. T. Sandwell (National Geodetic Survey, Charting and Geodetic Services, National Ocean Service, NOAA, Rockville, MD 20852)

A fracture zone (FZ) model is constructed from existing models of the thermal and mechanical evolution of the oceanic lithosphere. As the lithosphere cools by conduction, thermal and mechanical boundary layers develop and increase in thickness as age. Surface expressions of this development, such as topography, and deflection of the vertical (i.e., gravity field), are most apparent along major FZ's because of the sharp age contrast. A simple model, including the effects of lateral heat transport but with no elastic layer, predicts that variations in seafloor depth and deflection of the vertical will decay increasingly smooth and ultimately disappear as the FZ ages. Observations, however, show that both the FZ topography and the deflection of the vertical remain sharp as the FZ evolves. These two observations, as well as the observed asymmetry in deflection of the vertical profiles across the Udintsev, Eltanin and Menard FZ's, are explained by including a continuous elastic layer in the model. The asymmetry in deflection of the vertical is a consequence of elastic thickness variations across the FZ. [illegible] Elastic models of FZ's will be used to assess [illegible] effects across FZ's. [illegible] (Fracture zones, geoid, thermo-mechanical)

J. Geophys. Res., B, Paper 4B1125.

Geomagnetism and Paleomagnetism

2530 Spatial variations (anomalies)
MEAN IONOSPHERIC FIELD CORRECTION FOR MAGSAT DATA
N. Yanagisawa (Institute of Space and Astronautical Science) and M. Kono

To obtain a meaningful anomaly map showing magnetic fields of crustal origin from satellite observations, it is necessary to adequately account for and subtract the fields generated by the currents flowing in the ionosphere. Conventionally, corrections are made separately for each path by empirical methods of fitting and subtracting linear, quadratic, or harmonic functions from the original data. This procedure, however, lacks a sound physical basis. We examined the field components after the main field and the magnetospheric field were subtracted from Magsat data, and found certain structures in the residual field. The residual fields at 0600 and 1800 local times were separately averaged over longitude to obtain the effective contribution of ionospheric current system at these local times, which is called the Mean Ionospheric Field (MIF). To obtain the crustal anomalies, the MIF was subtracted from the residual fields. To account for the day-to-day variation in the ionospheric current system, and for the difference in satellite altitude, anomaly maps are constructed on 5°×5° grid averages. The dawn and dusk anomaly maps after the correction agree well with each other, showing that the effect of the ionospheric field is well taken care of by the MIF correction. The amplitude of anomalies is large even at comparatively long wavelength and the maps successfully represent these crustal anomalies which have been greatly reduced in the previous maps. (crustal anomalies, ionospheric field, Magsat).

J. Geophys. Res., B, Paper 4B1059.

2530
SCALAR MAGNETIC ANOMALIES OF CANADA AND NORTHERN US DERIVED FROM MAGSAT DATA
J. Arkani-Hamed Department of Geology, University of Toronto, Toronto, Ontario M5S 1A1, W.E.S. Urquhart and D.W. Strangway

The total magnetic field of the Earth over Canada and the northern United States is sampled along individual orbits (passes) of the magnetometer satellite (MAGSAT) on the basis of data extracted from the MAGSAT Chronicle tapes. The main magnetic field at a given sample point is calculated using the main field model by Langel et al. (1982a) and then subtracted from the sampled value. The external magnetic field contribution is partially removed by a quadratic function fitted to each individual pass. The resulting magnetic residuals are resampled at 55 km by 55 km grid points on an equal area projection and subsequently contoured. The dawn passes yield a magnetic map that is different than the dusk passes, implying that the remaining external magnetic field component has a dawn-dusk asymmetry. The component is further suppressed by applying a band-pass filter in the frequency domain. The magnetic anomaly map derived by averaging the dawn and the dusk band-pass filtered maps show the main features seen on the aeromagnetic maps of Canada and the United States. The map also shows that the Appalachian and the Cordilleran orogens and the Grenville-Superior suture zone are magnetically low regions whereas the craton basins such as the Michigan, the Thelon and the NE British Columbia Basin are magnetically high areas.

J. Geophys. Res., B, Paper 4B1026.

2560 Paleomagnetism
PALEOGEOGRAPHIC AND TECTONIC EVOLUTION OF SOUTHERN TIBET SINCE MIDDLE CRETACEOUS TIME: NEW PALEOMAGNETIC DATA AND SYNTHESIS
J. Achache (Institut de Physique du Globe et Département des Sciences Physiques de la Terre, Universités Paris 6 et 7, 75005, Paris, France), V. Courtillot and Y. Zhou

During the second French-Chinese paleomagnetic campaign in Tibet, in the summer of 1981, we sampled the middle Cretaceous red beds of the Takena Formation and the Cenozoic volcanics of the Lingzizong formation. A detailed analysis of about 400 specimens of red beds reveals a stable component of normal magnetization in the north of the Lhasa block (north of the Nyainqentanglha range) and two stable components in the south (LT, HT) where the red beds are more strongly folded and are unconformably overlain by the Lingzizong volcanics. All three components are carried by hematite. [illegible] from 400° to 600°C for LT and up to the Néel temperature of hematite for both N and HT. LT is shown to postdate the folding of the Takena, whereas N and HT both indicate a positive fold test at the 95% probability level. In addition, a small (less than 10% of the natural remanent magnetization) antiparallel component is superimposed in most samples and may be consistent with a model of long-term acquisition of a chemical remanent magnetization for the red beds. Analysis of the volcanics reveals a single stable component with normal polarities, carried either by hematite or magnetite. The paleomagnetic directions indicate that (1) the Lhasa block stood at 12.5±4°N by Upper Cretaceous and at 13.9±4.7°N in the Paleocene-Eocene, thus confirming the limited displacement of the margin of Eurasia between Albian-Aptian (deposition of the red beds) and Eocene (onset of the India/Asia collision). These values imply crustal shortening by as much as 1900 ± 850 km north of the block (since the Upper Cretaceous) and by 1400 ± 1200 km south of the block (since the onset of the collision). (2) Southern Tibet formed a single tectonic unit by middle Cretaceous time, and (3) no differential rotations are observed within the block and related to the collision. These rotations are discussed in the frame of a recent propagating extrusion tectonics model. This study confirms the close paleogeographic relationship between Indochina (Khorat plateau) and Southern Tibet prior to the India/Asia collision. (paleomagnetism, Tibet, crustal shortening, continental collision).

J. Geophys. Res., B, Paper 4B0446.

2599 General
MAGSAT AND POGO MAGNETIC ANOMALIES OVER THE LORD HOWE RISE: EVIDENCE AGAINST A SIMPLE CONTINENTAL CRUSTAL STRUCTURE
H. Frey (Geophysics Branch, Goddard Space Flight Center, Greenbelt, Maryland, 20771)

MAGSAT average scalar and POGO reduced-to-pole magnetic anomaly data both show prominent positive features over the Lord Howe Rise. Although generally assumed to be continental in nature, the Lord Howe Rise cannot simply be submerged ordinary continental crust, which would produce a relative anomaly low with respect to the more strongly magnetized adjacent oceanic crust. Three dimensional modelling of the plateau, using the known crustal structure and assuming an induced origin for the satellite-elevation anomaly, leads to a model in which the lowest crustal layer in an otherwise "continental" crustal structure has an unusually high susceptibility in the range 0.008–0.010 (SI units). Replacement of a portion of the lowest layer by a high susceptibility rock type may be related to the subsidence of the plateau. (Magnetic anomalies, crustal structure, oceanic plateaus).

J. Geophys. Res., B, Paper 4B1118.

Hydrology

3110 Erosion and sedimentation
[illegible]
W. E. Dietrich [illegible] University of California, Berkeley [illegible]

Bedload transport [illegible] meandering river [illegible] appropriate boundary [illegible] equations. The zone of [illegible] an outward shifting [illegible] stress [illegible] (Bedload transport [illegible]

Water Resour. Res., Paper [illegible]

3110 Erosion & sedimentation
AN EVALUATION OF METHODS FOR CALCULATING THE CONCENTRATION OF SUSPENDED BED MATERIAL IN RIVERS
J. E. Pizzuto (Dept. of Geology, University of Delaware, Newark, DE 19716)

A modified Rouse equation is used to predict the average concentration of suspended bed material in rivers and canals with sandy, dune-covered beds. Equations of Einstein, Itakura and Kishi, and Engelund and Fredsoe are used to calculate the absolute concentration near the bed (C_a). Calculations based on the Engelund-Fredsoe equation are consistently about 31 times too high. A modified Einstein equation overpredicts high concentrations and underpredicts low concentrations. The median predicted concentration is only 20% too high, however. The Itakura and Kishi equation is the most successful theory; predicted concentrations are overestimated by only 50% on the average. Better results, however, are obtained using a constant value of 22258 ppm for C_a in the Rouse equation, suggesting that C_a varies within a much smaller range than is predicted by current theories. A simple regression equation is the most successful of all of the methods tested here. (Suspended sediment transport, modelling).

Water Resour. Res., Paper 4W0979.

3130 Groundwater
A FINITE ELEMENT DUAL MESH METHOD TO CALCULATE THE NODAL DARCY VELOCITIES IN NONHOMOGENEOUS AND ANISOTROPIC AQUIFER
Yedat Batu (NUS Corporation, Park West Two, Cliff Mine Road, Pittsburgh, PA. 15275)

A finite element dual mesh method is developed to calculate the horizontal and vertical Darcy velocity components in a highly nonhomogeneous and anisotropic aquifer of constant porosity under steady flow conditions. The finite element method is used to calculate the total head distribution. The finite-difference forms of the total head gradients are used to calculate the Darcy velocity components. It is shown that the dual mesh method is suitable for calculating the nodal Darcy velocities with acceptable accuracy. The continuity principle is satisfied to an acceptable degree. The results are compared with an analytical solution and the comparisons are excellent. The results are also compared with another method proposed by Gureghian (1981) and Yeh (1981), and it is observed that the agreement is reasonably good. The dual mesh method can be applied to any nonhomogeneous and anisotropic porous medium to calculate the nodal Darcy velocities.

Water Resour. Res., Paper 4W1039.

3150 Precipitation
A HYDROLOGICALLY USEFUL STATION PRECIPITATION MODEL
2. CASE STUDIES
K.P. Georgakakos and R.L. Bras (Civil Engineering Department, Massachusetts Institute of Technology, Cambridge, MA, 02139)

A physically based model of precipitation at a point, developed by the authors in an accompanying paper, is used to make rainfall and snow predictions at locations in the United States and Venezuela. The model is utilized in off-line and real time modes. The latter involves the use of a Kalman filter. Results indicate that the parameterization suggested here is quite robust, comparing favorably with locally calibrated linear regression alternative models. Ideas for future work are given. (precipitation model, cloud microphysics, precipitation predictions).

Water Resour. Res., Paper 4W1076.

3199 General (Hydrocarbon migration)
A MATHEMATICAL MODEL OF COMPACTION-INDUCED MIGRATION
S. Rosenblat (Department of Mathematics, Illinois Institute of Technology, Chicago, Illinois, 60616)

A theoretical study is made of the dynamics of fluids in a non-trivial layer of porous material subject to vertical compaction. It is shown that during the compaction process fluid may be expelled from the layer both vertically and horizontally. When two immiscible fluids are present in the compacting layer the degree to which each is expelled depends on several factors, most importantly their initial saturations and their viscosity ratio. It is shown that there is a trend towards an equilibrium saturation, in the sense that large saturations tend to decrease during compaction while low saturations tend to increase. Some potential implications for explaining hydrocarbon migration are suggested. (Hydrocarbon migration, compaction).

J. Geophys. Res., B, Paper 4B0404.

Meteorology

3715 Chemical Composition and Chemical Interaction
DIURNAL VARIATION OF ClO: IMPLICATIONS FOR THE STRATOSPHERIC CHEMISTRIES OF $ClONO_2$, HOCl, AND HCl
Malcolm K. W. Ko and Nien Dak Sze (Atmospheric and Environmental Research, Inc., 840 Memorial Drive, Cambridge, MA 02139)

Numerical results are presented for the diurnal variations of stratospheric species including the chlorine species. The calculated diurnal variation of the column density of stratospheric chlorine monoxide (ClO) appear to be in good agreement with the recent measurement obtained from ground-based millimeter-wave spectroscopy (Solomon et al., 1984, Science, 224, p. 1210). The observed large diurnal variation of the column density of ClO above 30 km can be understood in terms of various exchange processes between ClO_x (Cl + ClO) and the temporary chlorine reservoirs ($ClONO_2$ and HOCl). The rapid early morning rise in the column density of ClO above 30 km is mainly attributed to photolysis of $ClONO_2$ whereas its continual decrease during the night time may be attributed to the recombination of ClO with NO_2 forming $ClONO_2$ as the major product. The predicted diurnal behavior of the upper stratospheric ClO, however, is mainly due to the exchange between ClO and HOCl. Observation of the diurnal behavior of ClO in the upper stratosphere can place important constraints on the chemistry of HOCl. (chlorine monoxide, chlorine nitrate, diurnal variation, stratospheric model)

J. Geophys. Res., D, Paper 4D1155.

3725 Convection, turbulence and diffusion
COMMENT ON "CUMULUS CLOUD TRANSPORT OF TRANSIENT TRACERS"
L. Mahrt (Atmospheric Sciences Department, Oregon State University, Corvallis, Oregon, 97331)

Difficulties with application of Reynolds

averaging and eddy diffusivities to one-dimensional cloud models is discussed. Present usage is found to be mathematically inconsistent without further modification.

J. Geophys. Res., D, Paper 4D1038.

3735 Electrical Phenomena
FURTHER CHARACTERISTICS OF POSITIVE RADIATION FIELDS FROM LIGHTNING IN SWEDEN
Vernon Cooray (Institute of High Voltage Research, University of Uppsala, S-755 90 Uppsala, Sweden)
Characteristics of the fields radiated by lightning in Sweden have been reported recently by Cooray and Lundquist (J. Geophys. Res.,87, 11203-11214,1982). That study is supplemented here by presenting additional characteristics of those fields that are hypothesized to be produced by positive return strokes. The new data presented here indicate that the currents in the sources of these radiation fields are either similar in duration to the currents in negative return strokes or of longer duration. This is based on the observation that the duration of these radiation fields are either similar to that of negative return strokes or of longer duration. During the first 50 to 100 μs both normal and long duration waveforms, and hence the inferred currents, seem to behave in a similar manner. That is there is an initial peak in the first few tens of microseconds and then a decay. After this the field and the inferred currents in some positive strokes continue to decay and in others start to increase again and reach a second peak in few hundred microseconds. While the current is flowing the cloud seems to produce, in some cases, a burst of pulses with a separation between pulses of about 3 μs or less. The shape of the inferred long duration currents are similar to the shapes of the positive return stroke currents measured in lightning strikes to high towers.

J. Geophys. Res., D, Paper 4D0906.

3735 Electrical Phenomena (Thunderstorm Charging)
THE "RAIN-GUSH", LIGHTNING AND THE LOWER POSITIVE CHARGE CENTER IN THUNDERSTORMS
E R Jayaratne (Pure and Applied Physics Department, UMIST, Manchester, England) and C P R Saunders
Laboratory studies of charge transfer, when vapor-grown ice crystals bounce off a hailstone in simulated thunderstorm conditions, have shown that the sign and magnitude of the charge separated is a sensitive function of the cloud and cloud particle properties. In general at temperatures colder than -20°C, hail becomes negatively charged, but at warmer temperatures it becomes positively charged.
The formation of the lower positive charge center in thunderstorms, and the initiation of a lightning flash which precedes the commonly observed gush of rain on the ground, may be explained in terms of this charging process. (Thunderstorm Charging, lightning).

J. Geophys. Res., D, Paper 4D1147.

3735 (Electrical Phenomena)
LIGHTNING PHENOMENOLOGY IN THE TAMPA BAY AREA
David W. Peckham (Department of Electrical Engineering, University of Florida, Gainesville, FL, 32611) Martin A. Uman, and Chester E. Wilcox, Jr.
A lightning locating system employing two wideband, gated magnetic direction-finders was used to study the negative cloud-to-ground lightning in 111 storms which occurred on eight days during August, 1979, in the Tampa Bay Area of Florida. The storms were classified as 1) single-peak storms, spatially isolated groupings of lightning whose cloud-to-ground flashing rate vs. time curves exhibited a single peak; 2) multiple-peak storms, spatially isolated groupings of lightning with multiple-peak flashing rates; and 3) storm systems, two or more related single-peak and/or multiple-peak storms. The following parameters are given for single-peak storms, multiple-peak storms, and storm systems: duration, area, number of ground flashes, mean ground flash density, mean ground flashing rate, and maximum ground flashing rate averaged over a five-minute interval. Ground-flash counts are corrected for the location-system detection efficiency which varied from about 75 percent at close range to about 55 percent at 100 to 150 km. The mean duration of single-peak storms, multiple-peak storms, and storm systems was 41, 77, and 130 minutes, respectively; the mean area 103, 256, and 900 square kilometers, respectively; and the mean number of lightning flashes to ground 73, 210, and 887, respectively. The mean ground flash density for single-peak storms, multiple-peak storms, and storm systems was 18×10^{-3}, 15×10^{-3}, and 9.7×10^{-3} km^{-2} min^{-1}, respectively; and the mean ground flashing rate 1.7, 3.4, and 6.8 min^{-1}, respectively. The highest maximum ground flashing rate averaged over a five-minute interval for all single-peak storms, multiple-peak storms, and storm systems was 17, 22, and 32 min^{-1}, respectively, while the mean of the maximum flashing rates was 3.7, 7.3 and 14 min^{-1}, respectively. The relation between storm duration in minutes, D, and number of ground flashes, N_g, for single and multiple-peak storms can be described by $\log_{10} N_g = 0.0140 + 1.2$.

J. Geophys. Res., D, Paper 4D0995.

3770 Particles and aerosols
RATES OF DRY DEPOSITION DETERMINED USING WET/DRY COLLECTORS
H. V. Feely (Environmental Measurements Laboratory, U. S. Department of Energy, New York, NY 10014), D. C. Bogen, S. J. Nagourney and C. C. Torquato
Daily samples of dryfall were collected during the June 1982 Dry Deposition Measurement Intercomparison Study at Champaign, Illinois using six Aerochem Metrics wet/dry collectors. Upon completion of the field experiment, these samples were analyzed at the Environmental Measurements Laboratory for pH and for their concentrations of major inorganic constituents. Contamination by rain and bird droppings rendered a number of dryfall samples unusable. When data for these samples were removed, the remaining data displayed acceptable precision for sulfate, calcium and magnesium. The measured deposition rates varied between 7 and 73 μg $m^{-2}.s^{-1}$ for sulfate, between 7 and 44 for calcium, and between 0.8 and 9.1 for magnesium. The precision of the data for ammonium, nitrate and phosphate was poor, so we have not calculated deposition rates for these constituents. The measurements of the atmospheric concentrations of sulfate reported by the Illinois State Water Survey have been used to calculate deposition velocities for particulate sulfate for 18 daily samples, even though the aerosol sampler and the dry bucket of the wet/dry collector may not sample the same size population of particulates. These velocities ranged from 0.1 to 1.2 $cm.sec^{-1}$, with a median value of 0.4 $cm.sec^{-1}$ and a mean of 0.45 ± 0.31 $cm.sec^{-1}$.

J. Geophys. Res., D, Paper 4D1106.

3770 Particles and aerosols
SAGE SATELLITE OBSERVATIONS OF STRATOSPHERIC AEROSOLS FROM MOUNT ST. HELENS ERUPTION: A TWO WAVELENGTH ANALYSIS
J. LENOBLE, P. PRUVOST, C. BRAGNIER (Laboratoire d'Optique Atmosphérique - ERA 466 - Université des Sciences et Techniques de Lille - 59655 Villeneuve d'Ascq Cedex - France)
The Angstrom coefficient profiles deduced from 93 SAGE satellite observations in July 1980 between 50°N and 70°N have been used to study the variation of the aerosol size distribution in the Mount St. Helens aerosol layer. In most cases a layer of large particles corresponding to the maximum extinction at 18-20km is topped by a layer of small particles. The study of profiles averaged over 10° latitude bands for May to November 1980 have confirmed the extent of this situation, which contrasts with a rather constant size distribution within the unperturbed stratosphere in 1979. Assuming an equivalent log-normal size distribution with an effective variance 0.250, the logarithmic mode radius is found around 0.20 μm for the large particle layer and around 0.06 μm for the top layer. The inferred mass density profile is strongly influenced by this structure. (Stratospheric aerosols, satellite observation).

J. Geophys. Res., D, Paper 4D1108.

3790
THE MU RADAR: FIRST RESULTS USING A PARTIAL SYSTEM
S. Kato (Radio Atmospheric Science Center, Kyoto University, Uji uji), T. Ogawa, T. Tsuda, T. Sato, I. Kimura, S. Fukao
The MU radar (Middle- and Upper-atmosphere radar) of RASC (Radio Atmospheric Science Center, Kyoto University) is now partly in operation. The facility will be complete in 1985. The active array antenna system of the radar makes it possible to steer the radar beam in an interpulse period i.e. 400 μs. The antenna system consists of independently operative subgroups, each having 19 Yagis. We expect various sophisticated experiments by the system. A preliminary observation was successful to elucidate atmospheric motions during Typhoon No. 5 which approached the radar site in August, 1983. (MST radar, middle atmosphere, upper atmosphere)

Rad. Sci., Paper 4S1062.

3790 Meteorology Instruments and Techniques
TEST OF A PROTOTYPE EDDY ACCUMULATOR FOR MEASURING ATMOSPHERIC VERTICAL FLUXES OF WATER VAPOR AND PARTICULATE SULFATE
R.E. Speer (MD-57, U.S. Environmental Protection Agency, Research Triangle Park, N.C. 27711), K.A. Peterson, T.G. Ellestad and J.L. Durham
An eddy accumulator was developed and operated during the Dry Deposition Intercomparison Study at Champaign, Illinois in June, 1982. The system collected paired samples for water vapor and particulate sulfate flux measurements, one sample for upward eddies and the other for downward eddies. Nineteen water vapor samples were analyzed gravimetrically and two sulfate samples were analyzed by ion chromatography. Comparison of water vapor results with eddy correlation measurements showed that discrepancies exceeded predicted errors. No significant results were obtained from the sulfate samples.

J. Geophys. Res., D, Paper 4D1061.

Mineralogy, Petrology, and Crystal Chemistry

4280 Paragenesis, Petrography, and Petrogenesis
ORIGIN OF MESOZOIC AND TERTIARY GRANITE IN THE WESTERN UNITED STATES AND IMPLICATIONS FOR PRE-MESOZOIC CRUSTAL STRUCTURE. 1) ND AND SR ISOTOPIC STUDIES OF UNMINERALIZED AND CU, MO MINERALIZED GRANITE IN THE PRECAMBRIAN CRATON
G. L. Farmer (Los Alamos National Laboratory, MS-J514, Los Alamos, NM 87545) and D. J. DePaolo
In the Cordilleran region of the western U.S., Mesozoic and Tertiary peraluminous granitic rocks display regional variations in initial $^{143}Nd/^{144}Nd$ (ε_{Nd}). ε_{Nd} = -10 to -18 in southern Arizona, -17 to -19 in the northern Great Basin (NGB), and -20 in the northern Rocky Mountains. Initial $^{87}Sr/^{86}Sr$ values are between 0.710 and 0.721 and show no regional pattern. Metaluminous granitic rocks have a wider range of ε_{Nd} values extending from values similar to those of the peraluminous granites to much higher values. The $^{87}Sr/^{86}Sr$ values are mostly fairly low, between 0.705 and 0.710 except in the NGB where values as high as 0.7157 are observed. No systematic differences between the ε_{Nd} or $^{87}Sr/^{86}Sr$ values of Cu or Mo-mineralized and unmineralized granite were discerned. Comparison to ε_{Nd} values of exposed Precambrian rock suggests that the peraluminous granitic rocks were derived exclusively from felsic Precambrian basement rocks, with the regional variations in the granite ε_{Nd} values reflecting a regional variation in the average crustal ε_{Nd}. The Nd data confirm that the Precambrian basement underlying the NGB and eastern California is isotopically distinct from Precambrian crust in the remainder of the western U.S. Metaluminous granitic rocks are interpreted to have formed via mixing of mantle-derived magma and large proportions of low $^{87}Sr/^{86}Sr$ (granulite facies) lower crust, or possibly by anatexis solely of mafic lower crust. REE abundance patterns for metaluminous granite in the NGB are characterized by extreme LREE enrichment, consistent with the proposed origin for these rocks by mantle/crust mixing. Overall, the Nd data indicate that continental interior granitic rocks in the western U.S. were derived primarily from pre-existing crust and do not represent significant juvenile additions to the continent.

J. Geophys. Res., B, Paper 4B0982.

4260 Petrogenesis
NUCLEATION, CRYSTAL GROWTH AND THE THERMAL REGIME OF COOLING MAGMAS
G. Brandeis (Laboratoire de Géochimie et Cosmochimie, Institut de Physique du Globe et Universités de Paris 6 et 7, 4 place Jussieu, 75230 Paris Cedex 05, France), C. Jaupart and C.J. Allègre
Crystallization at the margin of a quiet cooling magma has been studied numerically, taking into account the kinetics of crystallization. The variables are the latent heat value, the growth and nucleation functions, the initial magma temperature and the thermal contrast between magma and country rock. We have investigated a wide range of values for these parameters corresponding to natural conditions. We show that after a highly transient stage crystallization tends towards an equilibrium between heat production (latent heat release) and heat loss. Given the small diffusivity of country rocks, latent heat release is the main factor controlling the temperature evolution. In order to minimize the latent heat release, crystallization occurs at a temperature where nucleation is small. This can be close to either the liquidus or the solidus, depending on the initial conditions. The main process controlling crystallization is nucleation and not crystal growth. Nucleation occurs as a series of sharp pulses followed by longer periods of crystal growth. The nucleation pulses give birth to thermal oscillations. These oscillations can be sustained if the interior magma temperature is above the liquidus independently of the heat loss mechanism. We show that the phenomenon occurs on the scale of a few centimeters which corresponds to the inch-scale layering of many ultrabasic complexes. The model allows us to calculate crystal sizes which are in good agreement with geological observations. The crucial parameters which determine crystal size variations near the margins of igneous bodies are the initial thermal conditions as well as the nucleation and growth functions. In the main cooling regime close to the liquidus, significant size variations can be created by small thermal disturbances. (Crystallization, crystal size, thermal conditions).

J. Geophys. Res., B, Paper 4B1067.

4260 Petrography (Ocean Floor basalts)
SEGREGATION VESICLES OF OCEAN FLOOR BASALTS (I).
D. Bideau (Centre Océanologique de Bretagne, BP 337, 29273 Brest Cedex, France), and R. Hekinian.
This section studies of about one hundred rock samples recovered from the Mid-Atlantic Ridge (FAMOUS area near 37° N) show that the occurence of segregation vesicles is common but restricted to particular textural zones corresponding to the inner portion of the pillows. A detailled study of an aphyric olivine-basalt suggests that the formation of segregation vesicles is a progressive process which occurs during a period of the cooling-time where viscous deformation is still possible. This study provides criteria for selecting samples which may be oriented by the method of Bideau et al., (1977). This method is helpful for paleomagnetic studies on dredged basalts from the ocean floor. (basalts, segregation vesicles, crystallization process).

J. Geophys. Res., B, Paper 4B0584

4760 Paragenesis, petrography, and petrogenesis
THE GEOMETRY AND HIGH-TEMPERATURE BRITTLE DEFORMATION OF THE SKAERGAARD INTRUSION
D. Norton (Department of Geosciences, University of Arizona, Tucson, AZ 85721), H. P. Taylor Jr., D. K. Bird
The Skaergaard magma chamber formed approximately 55 m.y. ago along the embryonic rift between N. America and Europe as tholeiitic basalt magma flowed upward along fractures in basement gneiss and then infiltrated the stratigraphic unconformity at the base of a 7-9-km-thick section of continental basalts. The magma deflected and faulted the overburden as it formed a 3-km-thick, 167 km³, laccolith-like chamber with elliptical form (a=8 km, b=6 km) in map view. As the chamber grew, its feeder pipes were eroded into conical depressions; blocks of gneiss were rafted to the chamber top, and some blocks were fused and entrained in the main magma as "immiscible" fluids. Crystallization and cooling produced at least four distinct fracture events: (1) At 1050°-1000°C, residual magma accumulated in fractures in the Layered Series, forming gabbro pegmatites. (2) At 1050°-700°C, near-vertical fractures were formed, providing channels for the main pulses of meteoric hydrothermal activity; these fractures developed near the margin of the magma chamber, then expanded outward into the permeable basalts and inward, following the gabbro-magma interface. Ground waters derived from joints in the surrounding basalts flowed into the gabbro, were heated, lowered the $^{18}O/^{16}O$ ratio of the intrusion, and filled its fractures with hornblende, clinopyroxene, biotite, and magnetite. (3) At 800°-750°C, volatile-rich granophyric melts derived from stoped blocks of basement gneiss expanded and crystallized as dike-like bodies in the gabbro. (4) Below 700°C, fractures continued to form and hydrothermal activity continued to cool the intrusion. The relative age, abundance, continuity, and mineralogy of the veins are consistent with parameters used in previous studies of this intrusion that predict the occurrence of a high-temperature hydrothermal system and a time- and volume-averaged permeability of 10^{-13} cm². Our new data indicate that the permeability of the layered gabbro decreased with time because the flow channels were sealed by high-temperature mineral deposition. We thus conclude the following: (1) layered gabbros fracture in response to local stress at conditions just below their solidus temperature, if the confining pressures are typical of the upper crust. This observation contravenes the conceptual viewpoint that the style of deformation at such elevated temperatures is only by plastic flow; and (2) because an extensive fracture network develops at these near-solidus temperatures in layered gabbros, the bulk of the hydrothermal alteration of such bodies takes place at extremely high temperatures. This helps clarify the apparent paradox that extreme ^{18}O depletions are found in "fresh" layered gabbros. (Hydrothermal systems, oxygen isotopes, vein mineralogy, magma chambers).

J. Geophys. Res., B, Paper 4B0874

4299 General (Remote Sensing of Granite)
GRANITIC TERRAINS VIEWED REMOTELY BY SHUTTLE INFRARED RADIOMETRY: SOME COMPOSITIONAL PREDICTIONS
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Ratios of intensities of near-infrared spectral bands, measured in reflectance, quantitatively predict the iron content of granitic rocks. Such data from the 1.6 μm and 1.05 μm bands of the Shuttle Multispectral Infrared Radiometer (SMIRR) have been used to study granitic rocks along orbits crossing Baja California, Mexico, and the Eastern Desert of Egypt. Both regions are arid, relatively to essentially free of vegetation and there is no indication in the spectra that surface chemical alteration masks the true composition of the unweathered rock. Predicted values of iron are consistent with known compositional types of most of the rocks along the orbital paths. Results demonstrate that the near-infrared method used is a powerful technique to average the variability of these rocks on the scales of meters to kilometers. (Granite, Shuttle, infrared, remote sensing).

J. Geophys. Res., B, Paper 4B0936

Oceanography

4705 BOUNDARY LAYER AND EXCHANGE PROCESSES SPATIAL VARIATION OF SEA SURFACE TEMPERATURE AND FLUX-RELATED PARAMETERS MEASURED FROM AIRCRAFT IN THE JASIN EXPERIMENT
W. Timothy Liu (Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109) and Kristina B. Katsaros (Department of Atmospheric Sciences, University of Washington, Seattle, WA 98195)
Spatial variation of some parameters measured on two aircraft flying 100 km box and 200 km triangular patterns at low levels in the atmospheric boundary layer during the Joint Air Sea Interaction Experiment in the North Atlantic was studied. The variation should be representative of summer conditions in mid-latitude oceans.
The variance density of remotely sensed sea surface temperature, corrected for sky reflection, is found to depend on the one-dimensional wavenumber raised to the power of approximately -5/3. Non-uniform clouds add low frequency variance to observations of a downward looking radiometer and result in steeper slope of the spectra of uncorrected sea surface temperature.
Turbulent fluxes of momentum, sensible heat and moisture were determined with the bulk formulas from the parameters - wind speed, temperature, specific humidity and sea surface temperature, measured from the aircraft. The averages of these fluxes over each flight leg were compared with the fluxes determined from the parameters averaged over the same leg. The difference is negligible, showing that spatially averaged observations, such as those from spaceborne sensors, can be used in the bulk formulas to evaluate the fluxes. (Sea surface temperature, fluxes)

J. Geophys. Res., C, Paper 4C1097.

4713 Circulation
GENESIS AND EFFECTS OF LONG WAVES IN THE PACIFIC
Donald V. Hansen (NOAA/AOML, Miami, Florida 33149) and Carl A. Paul
Mesoscale eddy motions associated with cusp-shaped waves about 1000 km long observed in SST patterns in the equatorial Pacific Ocean were investigated using satellite-tracked drifting buoys. The eddy kinetic energy, like the SST frontal wave pattern, is situated primarily north of the equator. The meridional structure of the mesoscale motion provides strong support for recent theoretical work that attributes the waves and associated mesoscale eddies to shear instability of the mean zonal currents. Calculation of kinetic and potential energy conversions by the waves indicate an e-folding time for the perturbation of about 2 weeks, and a braking influence on the mean zonal flow equivalent to a change of a few tenths of a dyne/cm² in the surface wind stress. A meridional eddy heat flux, convergent on the equator, also is associated with the eddies. Within 2° of the equator, this eddy heat flux is of sufficient magnitude to offset as much as two-thirds of the mean meridional heat flux divergence associated with the near equatorial Ekman divergence and upwelling. (Mesoscale eddies, equatorial currents, shear instabilities, heat flux).

J. Geophys. Res., C, Paper 4C1033.

4725
LOW FREQUENCY SEA LEVEL VARIABILITY IN THE VICINITY OF THE EAST RIVER TIDAL STRAIT
Robert E. Wilson (Marine Sciences Research Center, State University of New York, Stony Brook, New York 11794), K-C. Wong and Ronald Filadelfo
The East River is a narrow tidal strait connecting Long Island Sound with the lower Hudson Estuary; the Sound and Estuary both communicate with the New York Bight. Subtidal fluctuations in sea level difference between the ends of the strait which are coherent with barotropic flow through the strait are produced mainly by direct setup in the Sound and Estuary and by sea level fluctuations (primarily wind forced) in the Bight. Approximately 70% of the variance in subtidal sea level difference can be accounted for by the two components of wind stress. The direction of dominant wind forcing (wind stress direction producing maximum response) varies considerably with frequency. Response functions relating sea level difference to wind stress components computed for 128 day series for sea level and winds allow us to interpret the direction of dominant forcing in terms of the relative contributions of direct setup and sea level fluctuations in the Bight.

J. Geophys. Res., C, Paper 4C1074.

4730 Internal waves
EQUATORIAL SEA LEVEL RESPONSE DURING THE 1982-83 EL NINO
R. Lukas (JIMAR, University of Hawaii, Honolulu, Hawaii, 96822), S. P. Hayes and K. Wyrtki
During the 1982-83 El Nino/Southern Oscillation event, sea level across the width of the equatorial Pacific adjusted to the reversal of the equatorial trade winds, and by the end of 1982, the normal sea level slope across the Pacific had been eliminated. The transfer of warm upper ocean water from the western Pacific to the eastern Pacific was accomplished by a combination of direct wind forcing as the wind anomaly crossed the basin and by mass flux induced by free equatorial waves.
The importance of equatorially trapped Kelvin waves of first and second vertical mode during the onset of the 1982-83 El Nino is inferred from the cross correlation statistics between central and eastern Pacific sea level stations, and between wind variations in the western Pacific and equatorial sea level stations to the east. The different propagation speeds of these two modes appears to be responsible for the observed change in shape of the major sea level signals during the 1982-83 event. Tentative evidence for first baroclinic mode, first meridional mode Rossby waves is also presented. (Equatorial waves, El Nino, sea level).

J. Geophys. Res., C, Paper 4C1035.

4740 Marine geological processes (Beaches, Turbidity Currents, Sedimentation)
ON THE MOTION OF VERY SMALL BODIES IN WATER WAVES
L.A. Giménez-Curto (Oceanographical and Ports Engineering Department, University of Santander, Santander, Spain.
Some equations describing the motion of a small, isolated body, that moves in translational motion through a fluid which is itself in unsteady and non-uniform motion are derived. Using a perturbation scheme a simple, and quite general solution is obtained for the leading order approximation of the velocity of very small bodies in water waves. This solution shows that, at least under certain general conditions the hypothesis of some delay time is sound, although this time is not the same for the vertical velocity component as for the horizontal one. Main assumptions used in this derivation are that flow accelerations are small compared with gravity and that $\omega w_f/g \ll 1$, which defines what is called 'very small body', w_f being still water terminal fall velocity, ω angular frecuency and g acceleration of gravity. (Water waves, Sediment Motion, Hydrodynamics, Small Bodies).

J. Geophys. Res., C, Paper 4C1032.

4765
REMOVAL OF AMBIGUITY OF TWO-DIMENSIONAL POWER SPECTRA OBTAINED BY PROCESSING SHIP RADAR IMAGES OF OCEAN WAVES
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From a single ocean surface image it is possible to determine the direction of surface waves up to an ambiguity of 180°. The spatial power spectrum of the image shows the same ambiguity because it is symmetric for reflections at the origin in wave number space. By taking two successive wave images the propagation direction can be determined uniquely. We present an analysis that generates non symmetric wave spectra from two successive wave images providing a unique wave direction for each spectral component.

J. Geophys. Res., C, Paper 4C1094.

4770 Turbulence and diffusion
EFFECTIVE DIFFUSIVITIES WITHIN OCEANIC THERMOHALINE STAIRCASES
Dan Kelley (Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, Canada B3H 4J1)
A scale for the thickness of layers in regular "diffusive"-type thermohaline staircases, derived from dimensional analysis, is found to collapse oceanic data. Combining this scale with laboratory-derived double-diffusive flux laws, we formulate effective diffusivities for salt, heat and density. The diffusivities depend on the Turner number, R_ρ, but are independent of the Brunt-Vaisala frequency. For R_ρ near 1, the diffusivities for salt and heat are approximately equal ($\approx 10^{-4}$ $m^2 s^{-1}$). They decrease roughly as R_ρ^{-4}, and R_ρ^{2}, respectively, over the oceanic range $1 < R_\rho < 10$. (Double-diffusion, thermohaline staircases, diffusivities).

J. Geophys. Res., C, Paper 4C1072.

4790 Instruments and Techniques (Oceanography)
ESTIMATES OF THE GEOSTROPHIC STREAM FUNCTION IN THE WESTERN NORTH PACIFIC FROM XBT SURVEYS.
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The upper ocean temperature and dynamic height fields are correlated in the western North Pacific Ocean. This relationship can be used to map a relative geostrophic stream function of the Kuroshio Extension using temperature data from expendable bathythermograph (XBT) surveys. We have examined the ability of the North Pacific ship of opportunity XBT program, known as TRANSPAC, to carry out this procedure. Estimates of 600/1200 db geostrophic shear were generated from the XBT data utilizing objective mapping techniques. These estimates were compared with measured currents at 600m relative to 1200m along 152°E from 27.7°N to 42°N. The estimated and measured relative currents are positively correlated, with an rms error of ±6 cm/sec over a measured dynamic range of 30 cm/sec. However, the XBT estimated shears consistently underestimate the measured values by a factor of 2 to 3. The underestimate of the amplitude is the result of both undersampling and mapping procedures that eliminate high wavenumber contributions of the dynamic height variability. These factors appear to be responsible for previous differences in amplitude between directly measured and TRANSPAC XBT estimated values of relative eddy kinetic energy and Reynolds stress. To monitor the Kuroshio Extension variability in the future, it is recommended that TRANSPAC XBT resources in the western North Pacific concentrate on obtaining a denser sample of the field during the fall and winter seasons because of incomplete ship track coverage in spring and summer. (Geostrophic Flow, XBTs)

J. Geophys. Res., C, Paper 4C1034.

4790 Instruments and techniques
RESOLUTION, BIAS, AND VARIANCE IN TOMOGRAPHIC ESTIMATES OF SOUND SPEED AND CURRENTS
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The Backus-Gilbert method is used to evaluate the quality of estimates of sound speed anomaly and (two) current components obtained from acoustic travel time data in a horizontal ocean slice. The approach is more flexible than previous ones in that reciprocal transmissions are not required and if present are not rigidly coupled by addition and subtraction. Nine categories of bias error are identified. They are associated with imperfect resolution of the three unknowns and cross contamination between them. Measures of these errors are developed which are system properties, as are stochastic error and resolution length. Bias error is calculated in numerical experiments and combined with stochastic error to obtain mean error. The various quantities which contribute to the mean error can be selectively reduced and brought into balance by trading off resolution. It is shown that it is possible in principle to estimate currents from one-way transmission data and results suggest that further study is merited. It is shown that array design can incorporate a mixture of reciprocal and non-reciprocal transmissions, and that equal weights for reciprocal data pairs are not always optimal. (Current estimates, tomography, inverse theory).

J. Geophys. Res., C, Paper 4C0930

4799 General (Oceanography)
ATMOSPHERIC FORCING OF INTERANNUAL VARIABILITY IN THE NORTHEAST PACIFIC OCEAN, CONNECTIONS WITH EL NINO
W.J. Emery (Department of Oceanography, University of British Columbia, Vancouver, B.C., Canada V6T 1W5) and K.P. Hamilton
The nature and causes of the observed interannual variability of oceanic conditions in the Northeast Pacific were investigated using a variety of meteorological and oceanographic data sets. An examination of a long series of seasonal mean atmospheric sea level pressure (SLP) charts showed that, when the winter average SLP pattern in the North Pacific varies significantly from climatology, it tends to do this in one of two characteristic ways. In particular, in some winters there is an anomalously strong circulation which differs from climatology mainly in having an intensified Aleutian low. In other winters, there is an anomalously weak atmospheric circulation; this is almost invariably associated with the westward displacement of the Aleutian low and the production of a separate, but much weaker, low in the Gulf of Alaska. The North Pacific winter SLP appears to have some relation to the Southern Oscillation (SO) and oceanic temperatures in the tropics. In particular, El Nino/Southern Oscillation (ENSO) episodes are generally coincident with strong North Pacific SLP patterns and often follow winters with weak SLP patterns. However, this relationship is far from being perfectly regular and predictable.
Interannual variations in the intensity of the North Pacific atmospheric surface circulation were found to be strongly correlated with the anomalies of both sea surface temperature (SST) and sea level height (SLH) at stations along the British Columbia coast. An intense Aleutian low is invariably associated with warm coastal waters and high coastal sea levels. By comparing a large number of Pacific SLP and SST maps, it was possible to verify that the relation between North Pacific SLP and oceanic surface temperature actually applies to the SST over much of the northeast Pacific (at least as far west as 150°W). The relationship of North Pacific SLP with the SO, together with the relationship between North Pacific SLP and oceanic conditions in the Northeast Pacific, can account for the observed general tendency for SST and SLH along the west coast of North America to be anomalously high during tropical ENSO episodes. On the other hand, the lack of a truly predictable relation between the Southern Oscillation and North Pacific SLP explains the fact that not all ENSO events are associated with warming of the Northeast Pacific. (El Nino, sea surface temperature, sea level pressure, teleconnections).

J. Geophys. Res., C, Paper 4C1002

Particles and Fields— Interplanetary Space

5340 Trapped Particles
ANISOTROPY CHARACTERISTICS OF GEOMAGNETICALLY TRAPPED IONS
H. A. Garcia (Space Environment Laboratory, NOAA/R/E/SE, Boulder, Colorado 80303), W. N. Spjeldvik
Radiation belt ions (protons + heavier ions) are found to exhibit quiet-time pitch angle anisotropies that vary significantly and non-monotonically with L-shell and energy in the range 30 keV to several MeV. Data from two spacecraft are reported: Explorer 45 measurements obtained in June 1972 and ISEE-1 measurements obtained from November 1977 through December 1978. Both data sets show that the radial distribution of pitch angle anisotropy contains one major minimum for most energies at some mid-range L-shell. The 1972 data collected over a fifteen day period in a localized region of the magnetosphere (between L=2 and L=5 in the afternoon local time sector) revealed an anisotropy profile for most energies that increased with lower L-shells below L ~ 3.5, minimized near L=3, then attained a local maximum around L ~ 4, and evolved to more isotropic distributions near the Explorer 45 orbit apogee at L=5.2. The 1977-78 pitch angle anisotropies observed by ISEE-1 were obtained over all local times from approximately L=2.5 to the outer limit of trapping. These data in general tended to confirm the 1972 finding of non-monotonic anisotropy distributions, but with some important modifications. The later quiet time distributions showed a broader region of low anisotropy and less regular L-shell dependence than the 1972 data, and showed systematic trends in the anisotropy that were clearly dependent not only on L-shell but also on energy. A single, major anisotropy minimum was observed at virtually every local time, the location of this minimum occurred at lower L-shells with progressively increasing energy. Comparison of the two quiet time data sets separated by about six years suggests that there may also be an anisotropy dependence on the phase of the solar cycle, possible resulting from ion composition differences or from different wave-particle interactions. (Ion pitch angle anisotropies, medium energy ions, particle measurements)

J. Geophys. Res., A, Paper 4A1143.

5340 Shock waves
A SIMPLIFIED MODEL FOR TIMING THE ARRIVAL OF SOLAR-FLARE-INITIATED SHOCKS
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The solar flare initiated shock can be considered to be an initially driven shock that converts into a wave as it propagates through the interplanetary medium. In our simplified shock modeling to estimate the time of the shock arrival at a specified position in space we assume that the shock is initially driven from the flare position at the velocity indicated by the type II solar radio burst. We assume the shock is driven until the initiating solar flare energy is somewhat expended. After this initially driven phase, the shock front then propagates with the characteristic speed expected of the shock front of a blast wave. In the interplanetary medium with its $1/r^2$ density dependence, the blast wave shock front speed should be proportional to $r^{-0.5}$. We find that this $r^{-0.5}$ speed dependence is a general characteristic of the shock front speed when the speeds are determined in the solar wind reference frame. The blast wave "rides over" the pre-existing solar wind so that the disturbance speed of the shock front at any instant of time is the speed of the shock front added vectorially to the solar wind speed. Application of these principles enables a consistent "timing" of solar-flare-initiated shock waves that is event independent. We show that this concept is consistent with the time-position profile derived from the analysis of kilometric type II events that are associated with interplanetary shocks. (shock waves, blast wave, solar-flare-initiated-shocks, solar wind).

J. Geophys. Res., A, Paper 4A8105.

5340 Shock Waves
DISTANT HELIOSPHERIC RESULTS ON INTERPLANETARY SHOCK PROPAGATION
J. D. Mihalov (Theoretical Studies Branch, NASA-Ames Research Center, Moffett Field, California, 94035)
Solar wind plasma data from Pioneers 10 and 11, and the Pioneer Venus Orbiter, for 1978 to mid-1981, have been examined for forward shock signatures, and associations have been made with solar flares. The numbers of flare-associated shocks observed at the various heliocentric distances of the spacecraft (ranging from 0.7 to 24 AU) are deduced, and the shock strengths and energies are given. Significantly fewer shocks associated with flares are observed at the greater distances, presumably because more cases have decreased below the threshold for inclusion. Three cases in which the same shock was probably detected by spacecraft at different heliocentric distances indicate deceleration and weakening at the greater distances. (Interplanetary shock waves, solar wind plasma, distant heliosphere).

J. Geophys. Res., A, Paper 4A8065.

5340 Shockwaves
A STUDY OF THE FORMATION, EVOLUTION AND DECAY OF SHOCKS IN THE HELIOSPHERE BETWEEN 0.5 AND 30.0 AU
Z. K. Smith (Space Environment Laboratory, NOAA R/E/SE, Boulder, Colorado, 80303), M. Dryer and R. S. Steinolfson
The spacial and temporal evolution of CIRs is examined between 0.5 AU and 30 AU using a solar wind simulation with a continuous sinusoidally-varying velocity, density, and temperature input pulse train. We show: (1) the well-known formation of forward-reverse MHD shock ensembles; followed by (2) their interaction that results in a highly nonlinear "pressure" wave that, eventually, reforms into a new but more irregular set of forward-reverse shock pairs. As a result of these compound interactions, the overall temperature decays much more slowly than the classical steady-state adiabatic radial dependency of $R^{-4/3}$.

J. Geophys. Res., A, Paper 4A1116.

5340 Shock waves
SHOCK ACCELERATION OF DIFFUSE IONS AT THE EARTH'S BOW SHOCK: ACCELERATION EFFICIENCY AND A/Z ENHANCEMENT
Donald C. Ellison (Center for Theoretical Physics, Astronomy Program, University of Maryland, College Park, MD 20742)
Observations of particle spectra, intensity, and enhancement of alpha particles over protons at diffuse ion events at the quasi-parallel earth bow shock are compared to a Monte Carlo simulation of diffusive shock acceleration. The simulation includes the back reaction of accelerated particles on the shock structure, particle escape at an upstream free escape boundary, and a low energy per nucleon threshold for thermal leakage of downstream, shock heated particles into the upstream region. The simulation assumes that the same scattering operator that gives rise to shock acceleration can also describe a viscous shock governed by hydrodynamic turbulence. This implies that accelerated ions can be drawn directly from the thermal solar wind with no separate suprathermal seed population. Good agreement between the simulation and observations made during nearly radial magnetic field configurations lends support to thermal leakage of downstream, shock heated ions as the mode of injection for diffuse ion events. (Shock acceleration, particle injection)

J. Geophys. Res., A, 4A8095.

5360 Solar wind interactions with moon and planets
GROWTH AND MAINTENANCE OF LARGE SCALE MAGNETIC FIELDS IN THE DAYSIDE VENUS IONOSPHERE
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Observations from the Pioneer Venus Orbiter magnetometer reveal large scale magnetic fields in the dayside ionosphere during or after periods of high solar wind dynamic pressure. Various hypotheses have been proposed concerning the spatial and temporal evolution of these magnetic structures. Here we examine the hypothesis that the field is produced by a diffusion/convection process rather than by currents driven by electric fields resulting from the solar wind interaction. Dynamic pressure variations occur on various time scales at Venus, producing transient and quasi-steady magnetization features. A one-dimensional diffusion/convection calculation is performed, using typical field and pressure values for a variety of altitudes. The ionopause is considered to be the altitude at which ionospheric thermal pressure is equal to the magnetosheath magnetic pressure, which in turn is well correlated with the normal component of solar wind dynamic pressure. A subsolar model of downward plasma velocity in the 140-290 km range is used. The calculated growth of the ionospheric magnetic field, and the resulting quasi-steady altitude profiles, compare favorably with the observed profiles. The majority of the observed magnetic structures are best explained as the quasi-steady effects of the solar wind dynamic pressure, which determines the altitude and magnetic field strength of the ionopause. (Venus, magnetic fields, ionosphere).

J. Geophys. Res., A, Paper 4A1124.

5370 Solar wind magnetic fields
LARGE-SCALE INTERPLANETARY MAGNETIC FIELDS: VOYAGER 1 AND 2 OBSERVATIONS BETWEEN 1 AU AND 9.5 AU
L. F. Burlaga (NASA/GSFC, Lab. for Extraterrestrial Physics, Greenbelt, MD 20771) L. W. Klein, R. P. Lepping, K. W. Behannon
The strength B of the interplanetary magnetic field observed by the Voyager spacecraft between 1 AU and 9.5 AU was found to decrease with distance R from the sun as $B \approx 4.75\,(1 + R^2)^{1/2}/R^2$, in agreement with the spiral field model. Between August, 1977 and July, 1979, when solar activity was increasing, corotating flows were observed at an average rate of at least 1 every 20 days, but the flows were evolving with time and seldom recurred from one solar rotation to the next without change. Many transient flows were also observed in this period. Large-scale fluctuations in B with respect to the average spiral field were observed in association with interplanetary shocks and corotating stream interfaces, and these fluctuations varied with time in association with changes of the flows. The amplitude of the fluctuations in B relative to the mean field was large. There was a tendency for it to increase with distance to 5 AU, but the temporal variations were comparable to or larger than the radial variations. At large distances, B and the plasma density increased together, consistent with the idea that the structure of the outer heliosphere may be determined by stream interactions. The width of interaction regions increased with R owing to expansion, and closely spaced interaction regions often coalesced. A 4-sector pattern was observed from day 287, 1977, to approximately day 173, 1978, followed by a 2-sector pattern which lasted to at least day 179, 1979. In the interval with 4 sectors, there were usually several small-amplitude peaks in B together with many transient streams and shocks on each solar rotation, whereas in the interval with 2 sectors there were 1 or 2 maxima in B together with interfaces and shock pairs on each solar rotation. Thus, the relatively abrupt change in sector pattern was accompanied by a change in the pattern of fluctuations in B and a change in the nature of the dominant flows. (Magnetic fields, shocks).

J. Geophys. Res., A, Paper 4A1142.

5376 Magnetic tail
BROADBAND ELECTROSTATIC NOISE IN THE MAGNETOTAIL: ITS RELATION TO THE PLASMA SHEET DYNAMICS
A. Nishida (Institute of Space and Astronautical Science, Komaba, Meguro, Tokyo 153, Japan), T. Hada, K. A. Anderson, R. R. Anderson, S. J. Bame and E. W. Hones, Jr.
Intense broadband electrostatic noise is often observed in the magnetotail when the fast tailward flow and the southward polarity of the magnetic field indicate the progress of reconnection. We compare features of the noise with simultaneous observations of the magnetic field, plasma and energetic electrons. The noise intensity seems to maximize when the plasma density minimizes and the energetic electron flux rises in a spike-like fashion, appreciably later than the onset of the fast tailward flow associated with the southward magnetic polarity. Spectral characteristics of the noise suggest that in its high frequency (f > f[illegible]) part at least the noise does not belong to normal modes of plasma waves. Several possibilities are considered for what this noise might be, including: quasi-thermal noise in the non-Maxwellian plasma, artificial noise generated by spacecraft interaction with the medium, or electrostatic noise with wavelengths less than a Debye length. (Electrostatic noise, magnetotail, reconnection)

J. Geophys. Res., A, Paper 4A1080.

5399 General (Shock Acceleration)
SHOCK DRIFT ACCELERATION IN THE PRESENCE OF WAVES
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Charged particle acceleration via the shock-drift mechanism at quasi-perpendicular shocks has generally been analyzed by assuming uniform, time-independent conditions at and near the shock. We present results from a model designed to study how the shock-drift mechanism is modified when wave activity is included in the shock's upstream and downstream vicinities. The technique involves numerically following test particle trajectories in the wave-shock system for pre-defined wave fields. In order to compare these results with those obtained in the scatter-free (i.e., non-wave) case, we restricted particles to a single shock encounter, which is here defined as the period during which the particle remains within a gyrodiameter of the shock. As a particular example, we injected ensembles of ions into a system consisting of a quasi-perpendicular shock moving through the interplanetary spectrum of ambient Alfven waves. As compared with a single encounter in the scatter-free limit, the inclusion of waves: (a) increases particle transmission through the shock; (b) produces broader energy distributions for reflected and transmitted particles, with high energy tails at energies several times the maximum energy obtained in the scatter-free case; (c) reduces anisotropies, particularly of reflected particles, but does not eliminate them. Also, for the range of particle energies studied, it was found that the approximate invariance of the magnetic moment for particle interactions with quasi-perpendicular shocks is no longer valid when waves are present. (Interplanetary shock acceleration)

J. Geophys. Res., A, Paper 4A1111.

Particles and Fields— Ionosphere

5505 Airglow
INTENSITY VARIATIONS OF GEOCORONAL BALMER ALPHA EMISSION 1. OBSERVATIONAL RESULTS P. Shih, F. L. Roesler, and F. Scherb Department of Physics, University of Wisconsin-Madison, Wisconsin 53706
Ground-based observations of geocoronal Balmer α (Hα) emission were performed with a large-aperture, high-etendue Fabry-Perot spectrometer at a resolving power of about 70,000, which clearly isolates the geocoronal emission from galactic and zodiacal light backgrounds. During each observing night, observations were conducted alternately between two directions, one at 65° zenith distance in the sun's azimuth and the other in the antisolar direction, to compare the emission primarily from single scattering of solar Lyman β with that primarily from multiple scattering, and to evaluate the intensity variations over various time scales. Accurate intensity calibration was obtained by observing astronomical photometric standard sources on each night of observation. The morning enhancement of the observed Hα intensities in both directions is 10%. Assuming single scattering dominates, the observed intensity variation seems difficult to reconcile with the standard diurnal variation model which implies an increase at mid latitudes of about 30% in the exobase hydrogen density between the evening period and the post midnight period. In contrast to the standard diurnal variation model, some satellite measurements indicate a morning hydrogen trough in northern mid latitudes, a result consistent with the present measurements. Detailed radiative transfer calculations and model refinements are required to clarify the situation. Comparisons of Hα intensities observed on different nights with the same scattering geometry reveal a clear inverse relationship between the geocoronal Hα emission rate and the exospheric temperature based on the Jacchia 1977 model. Preliminary calculation shows this Hα intensity variation agrees with the results of several satellite experiments which found that the variation of the exobase hydrogen density with temperature is less rapid than that predicted by consideration of Jeans escape as the only hydrogen escape mechanism.

J. Geophys. Res., A, Paper 4A8092.

5510
HIGH-LATITUDE INDICES OF ELECTRIC AND MAGNETIC VARIABILITY DURING THE CDAW-6 INTERVALS
H. W. Kroehl (NOAA National Geophysical Data Center, 325 Broadway, Boulder, Colorado, 80303) and Y. Kamide
For the two CDAW-6 intervals, we derived the global distribution above the north polar region of ionospheric currents, field-aligned currents, electric fields and Joule heat from magnetic variations recorded at 107 stations and modeled values of ionospheric conductance using the KRM method. In addition, we computed several scalar indices to summarize changes in the magnetic and electric fields at high latitudes. Correlation coefficients lie between 0.41 and 0.98 depending on the combination of indices and the characteristics of the interval. From the cross-correlation between the total auroral electrojet currents and the AU and AL indices of electrojet current density, we find that the latitudinal width of the westward electrojet expands (contracts) simultaneously with an increase (decrease) in current density. However, the lower correlation between AU and the total eastward current demonstrates the importance of changes of latitudinal width to the total current. The relatively poor correlation between AU and AL highlights the differences between the two indices and raises doubts about the meaning of the AE index. We notice that both electric potential and conductivity changes influence the electrojets. When the electric potential difference across the polar region is large relative to a given intensity of the total current, a convection current system characterizes the polar region. When both are of the same relative amplitude, a substorm expansion system prevails with the maximum electric potential difference focused across auroral latitudes. (Auroral, electrojets, ionospheric currents, magnetic indices, electric indices).

J. Geophys. Res., A, Paper 4A1089.

5515 Auroras
ACCELERATION OF BARIUM IONS NEAR 8000 KM ABOVE AN AURORA
H. C. Stenbaek-Nielsen, (Geophysical Institute, University of Alaska, Fairbanks, Alaska 99701) T. J. Hallinan, D. H. Wescott, H. Foeppl
A barium shaped-charge, named Limerick, was released from a rocket launched from Poker Flat Research Range, Alaska, on March 30, 1982, at 10:33 UT. The release took place in a small auroral breakup. The jet of ionized barium reached an altitude of 8100 km in 14.5 minutes after release, indicating that there were no parallel electric fields below this altitude. At 8100 km the jet appeared to stop. Analysis shows that the barium at this altitude was effectively removed from the tip. We conclude that the barium was actually accelerated upwards resulting in a large decrease in

the line-of-sight density and hence the optical intensity. The parallel electric potential in the acceleration region must have been greater than ~1 kV over an altitude interval of less than ~200 km. The acceleration region, although presumably auroral in origin, did not seem to be related to individual auroral structures, but appeared to be a large-scale horizontal structure. The perpendicular electric field below, as deduced from the drift of the barium, was temporally and spatially very uniform and showed no variation related to individual auroral structures passing through. (Aurora, electric fields, barium release).

J. Geophys. Res., A, Paper 4A1082.

5535 Interactions between waves and particles
MODULATIONAL INSTABILITY AND SOLITON FORMATION DURING IONOSPHERIC HEATING
G. L. Payne (Dept. of Physics and Astronomy, University of Iowa, Iowa City, Iowa 52242), D. R. Nicholson, R. M. Downie, and J. P. Sheerin

The most intense electric fields during ionospheric heating occur a fraction of a kilometer below the classical reflection point. At this location, the nonlinear evolution of Langmuir waves is studied within the context of the modified Zakharov equations. It is found that the modulational instability (oscillating two-stream instability) is more important than the three-wave parametric decay instability, leading to the rapid formation of solitons. (Modulational instability, soliton formation, ionospheric heating).

J. Geophys. Res., A, Paper 4A8177.

5545 Ionospheric Disturbances
THE ROLE OF FINITE PARALLEL LENGTH ON THE STABILITY OF BARIUM CLOUDS
J.L. Sperling (JAYCOR, San Diego, California 92138), J.F. Drake, S.T. Zalesak, and J.D. Huba

A simple model is used to show that the finite parallel length of ionospheric plasma clouds can affect the growth rate of striation instabilities (e.g., gradient drift). The finite parallel length of plasma clouds tends to favor the growth of striations with short perpendicular wavelengths.

J. Geophys. Res., A, Paper 4A8220.

5545 Ionospheric disturbances
EARTH'S MAGNETIC FIELD PERTURBATIONS AS THE POSSIBLE ENVIRONMENTAL IMPACT OF THE CONCEPTUALIZED SOLAR POWER SATELLITE (SPS)
M. C. Lee (Regis College Research Center, Weston, MA 02193), S. P. Kuo

It is predicted that the earth's magnetic field can be significantly perturbed locally by the microwave beam transmitted from the conceptualized solar power satellite (SPS) at a frequency of 2.45 GHz with incident power density of 230 W/m² at the center of the beam. The simultaneous excitation of earth's magnetic field fluctuations and ionospheric density irregularities is caused by the thermal filamentation instability of microwaves with scale lengths greater than a few hundred meters. Earth's magnetic field perturbations with magnitudes (~a few tens of gammas) comparable to those in magnetospheric substorms can be expected. Particle precipitation and airglow enhancement are the possible, concomitant ionospheric effects associated with the microwave-induced geomagnetic field fluctuations. Our present work adds earth's magnetic field perturbations as an additional effect to those such as ionospheric density irregularities, plasma heating, etc. that should be assessed as the possible environmental impacts of the conceptualized solar power satellite program. (Solar power satellite, thermal filamentation instability, ionospheric density irregularities).

J. Geophys. Res., A, Paper 4A1115.

5545 Ionospheric disturbances (plasma bubbles)
LONGITUDINAL VARIABILITY OF ANNUAL CHANGES IN ACTIVITY OF EQUATORIAL SPREAD F AND PLASMA BUBBLES
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Global distribution maps of equatorial spread F (ESF) activity for various annual periods were derived from the topside soundings by the Ionosphere Sounding Satellite -b (ISS-b) in 1978-1980. The ESF activity during the northern winter period reveals maximum enhancement at the Atlantic longitudes of large westward geomagnetic declination, and during the northern summer at the Pacific longitudes of large eastward declination. On several orbits passing over the region of the ESF activity enhancement, abrupt depletions of the electron density or equatorial plasma bubbles were observed at the satellite altitude of about 1100km. It has also been found that the background electron density distributions tend to be symmetric with respect to the magnetic equator in the region of the enhanced ESF activity and asymmetric in the region of the suppressed ESF activity. These observations are taken account for by the influence of a transequatorial thermospheric wind upon the suppression of the Rayleigh-Taylor type plasma instability. (Equatorial spread F, plasma bubbles).

J. Geophys. Res., A, Paper 4A1145.

5548 Plasma motion, convection, or circulation
A MODEL FOR THE PROPAGATION OF THE WESTWARD TRAVELING SURGE Paul L. Rothwell (Air Force Geophysics Laboratory, Hanscom AFB, Bedford, MA,01731) Michael B. Silevitch and Lars P. Block

A unified model is developed for the propagation of the Westward Traveling Surge (WTS) which can explain the diversity in the observed surge characteristics. We start with the Inhester-Baumjohann model for the surge region which implicitly includes both the Hall and Pedersen currents. It is found that precipitating electrons at the conductivity gradient modify the gradient, causing it to propagate as a wave front. The velocity of propagation is directly dependent on the ionization efficiency of the precipitating electrons and, therefore, increases dramatically when they become more energetic during substorm onsets. For example, we predict that when the incident electron energy changes from 1 keV to 10 keV the surge velocity should increase from 2 km/s to 14 km/s. The direction of the surge motion depends on the presence of polarization charges on the poleward surge boundary. This is related to the efficiency with which the poleward ionospheric currents are closed off into the magnetosphere by the field-aligned currents. Inclusion of the electron-ion recombination rate modifies the surge propagation velocity and leads to explicit expressions for the conductivity profile. Sufficient precipitation current is required to overcome electron-ion recombination in order for the surge to expand. When the precipitating current is less than this threshold the WTS retreats. Therefore, the model describes the ionospheric response to both the expansion and recovery phases of the magnetic substorm. (Aurora, ionospheric currents, electron precipitation).

J. Geophys. Res., A, Paper 4A0864.

5580 Wave Propagation
INTERPRETATION AND MODELING OF QUASIPERIODIC DIFFRACTION PATTERNS OBSERVED IN EQUATORIAL VHF SCINTILLATION DUE TO PLASMA BUBBLES
S. J. Franke (Department of Electrical and Computer Engineering, University of Illinois, Urbana, Illinois 61801), C. H. Liu and J. P. McClure

Quasiperiodic diffraction patterns have been observed in VHF scintillation recorded at Ascension Island in 1981. The patterns occur most often at the beginning or end of a scintillation patch and are shown to be consistent with those expected from irregularities having east-west scale sizes of a few hundred meters that are associated with the walls (edges) of equatorial plasma bubbles. By adjusting the geophysical parameters in a computer simulation of the amplitude fluctuations expected simultaneously at VHF, L-Band and C-Band we model a specific event in detail. The model contains information on the size and strength of the structures that cause the regular fading patterns. In addition, multi-frequency diffraction patterns are computed for a "phase screen" model based on high resolution measurements of a structured plasma bubble wall made using the AE-E satellite. The results are qualitatively very similar to the observations. Finally, implications of the model results for the extraction of information about the vertical structure of the irregularities are discussed. (Equatorial scintillation)

J. Geophys. Res., A, Paper 4A8125.

5599 (Plasma Instabilities)
UNIFIED THEORY OF THE POWER SPECTRUM OF INTERMEDIATE WAVELENGTH IONOSPHERIC ELECTRON DENSITY FLUCTUATIONS
R.N. Sudan (Laboratory of Plasma Studies, Cornell University, Ithaca, N.Y. 14853) and M.J. Keskinen

An extension of the Kolmogorov theory of fluid turbulence is used to develop a unified treatment of the power spectrum of intermediate wavelength electron density fluctuations in the equatorial and high latitude ionosphere. Favorable comparison is made between theory and experimental observations.

J. Geophys. Res., A, Paper 4A8108.

Particles and Fields—Magnetosphere

5720 Interactions between solar wind and magnetosphere
SOLAR WIND CONTROL OF MAGNETOSPHERIC PRESSURE (CDAW-6)
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The CDAW-6 data base is used to compare solar wind and magnetospheric pressures. The flaring angle of the tail magnetopause is determined by assuming that the component of solar wind pressure normal to the tail boundary is equal to the total pressure within the tail. Results indicate an increase in the tail flaring angle from 18° to 32° prior to the 1055 substorm onset and a decrease to 25° after the onset. This behavior supports the concept of tail energy storage before the substorm and subsequent release after the onset. (Magnetosphere pressure, tail flaring, solar wind pressure).

J. Geophys. Res., A, Paper 4A1087.

5736 Magnetic Tail
EVOLUTION OF THE EARTH'S DISTANT MAGNETOTAIL: ISEE-3 ELECTRON PLASMA RESULTS
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Electron plasma measurements made by ISEE 3 from October 18, 1982 through April 19, 1983 were examined for signatures identifying the spatial evolution of the lobe and plasma sheet of the earth's magnetotail out to distances of ~225 R_e. The lobe density distribution shows two peaks near earth (<60 R_e), a narrow peak at ~10^{-2} cm^{-3} representing quiet lobe and a second broader peak above 10^{-1} cm^{-3} representing boundary layer phenomena. At larger distances the lower density peak disappears and the remaining density peak (at ~10^{-1} cm^{-3}) becomes broader and contains a high density tail which extends well above 1 cm^{-3}. The increase in lobe density at large distances is believed to be due to plasma which crosses the magnetopause on open field lines along its flanks and drifts inward toward the plasma sheet. The plasma sheet density distribution shows only a slight decrease in density at larger radial distances. The temperature of the plasma sheet and lobe electron plasma decreases with increasing distance, with the plasma sheet temperature decreasing at a faster rate. The bulk flow velocity of the plasma sheet and lobe plasma increases dramatically at larger radial distances. The electron bulk velocity observed in the plasma sheet beyond 180 R_e often exceeds the normal solar wind velocity range (300-700 km/sec). The most striking result of this study is the observed evolution of the electron bulk velocity flow angle from a bimodal distribution near earth to a single tailward directed peak beyond 180 R_e. The decreasing amount of earthward flow with increasing distance directly implies that the location of the distant neutral line is usually within 120 R_e of earth, and rarely beyond 180 R_e. These observations also imply that the location of the neutral line is variable and dependent upon local interplanetary and geomagnetic conditions.

J. Geophys. Res., A, Paper 4A8049.

5770 Short-period variations of magnetic field
POLARIZATION OF GEOMAGNETIC SUDDEN COMMENCEMENTS OBSERVED BY GEOSTATIONARY SATELLITES
H. Nagano (Department of Physics, Gifu college of Dentistry, Gifu 501-02, Japan) and T. Araki

Using magnetic data from GOES 2 and 3 geostationary satellites for the interval from August 1978 to August 1980, local time dependence of polarization of geomagnetic sudden commencements (SC's) was statistically analyzed. The polarization in the plane perpendicular to the geomagnetic field is counter clockwise on the morning side (0h-12h LT) and clockwise on the afternoon side (12h-24h LT), when viewed along the field direction. This is consistent with the statistical results from ground-based magnetic data by Wilson and Sugiura [1961]. The demarcation line across which the polarization is reversed seems to vary in the time span between 11h and 14h LT. This time span may be due to different angles with which shock fronts or tangential discontinuities propagating in interplanetary space collide the magnetosphere. A latitudinal reversal of the polarization of SC observed on the ground does not seem to occur at geostationary orbit. (Geomagnetic sudden commencements, polarization, geostationary satellites).

J. Geophys. Res., A, 4A8153

5770 Short-period (less than 1 day) variations of magnetic field
RELATIONSHIP BETWEEN THE IMF MAGNITUDE AND Pc 3 MAGNETIC PULSATIONS IN THE MAGNETOSPHERE
K. Yumoto (Onagawa Magnetic Observatory and Geophysical Institute, Tohoku University, Sendai 980, Japan), T. Saito, B.T. Tsurutani, E.J. Smith and S.-I. Akasofu

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6140 (Magnetic Properties)
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7720 Electromagnetic Radiation
SOLAR IRRADIANCE VARIATION NEAR 2075 ANGSTROMS
L.A. Hall (Air Force Geophysics Laboratory, Bedford, Massachusetts, 01731) and G.P. Anderson

Measurements of solar radiation in the vicinity of the Al1 absorption edge at 2075 Angstroms provide a means of comparing the magnitude of the 11-year variation in solar activity with that of the 27-day variation. The ratio of the solar irradiance in the band 2030-2070Å to that in the band 2100-2140Å has been determined from five measurements made in the period 1977-1983. This ratio, as an almost purely relative measurement, avoids the problem of absolute irradiance comparisons over long periods of time. The magnitude of the 11-year effect in this ratio is about ± 1%, which is comparable to that in the 27-day effect measured at solar maximum. (solar ultraviolet, solar irradiance, solar variation).

J. Geophys. Res., D, Paper 4D0940

7730 Gamma ray astronomy
PRODUCTION OF HIGH ENERGY GAMMA RAYS BY COSMIC RAY INTERACTIONS IN THE ATMOSPHERE AND LUNAR SURFACE
D. J. Morris (NASA Code ES-62, Marshall Space Flight Center, Huntsville, AL 35812)

The production of gamma rays above 10 MeV by the interaction of cosmic rays in the atmosphere and the lunar surface is simulated using Monte Carlo methods. The calculation incorporates a new model of high energy nucleon-nucleus interactions based on empirical fits to inclusive cross sections for the production of pions and nucleons. The atmospheric gamma ray flux is calculated as a function of direction, energy, and atmospheric depth. These calculations are compared with observations from balloons and from the SAS 2 satellite. Estimates of the flux of earth albedo electrons produced by cosmic ray interactions are presented. The lunar gamma ray albedo is calculated and compared with an upper limit based on SAS 2 measurements. (gamma rays, cosmic rays, atmosphere, moon).

J. Geophys. Res., A, Paper 4A0765

7760 Radio Astronomy
COHERENCE LIMITS IN VLBI OBSERVATIONS AT 3 MM WAVELENGTH
A. E. E. Rogers (Haystack Observatory, Westford, MA 01886), A. T. Moffet, D. C. Backer, and J. M. Moran

VLBI experiments at a frequency of 89 GHz (3.4 mm wavelength) using hydrogen maser frequency standards show that under good atmospheric conditions coherence can be maintained for times up to 700 seconds, corresponding to an Allan standard deviation of approximately 10^{-14}. The stability appears to be largely limited by the phase noise resulting from fluctuations in delay through the troposphere. Methods of estimating the interferometer fringe amplitudes and closure phases in the presence of large phase fluctuations are examined. The spectrum and the Allan standard deviation of the observed phase fluctuations are derived. (Coherence, millimeter, troposphere, very long baseline interferometry).

Rad. Sci., Paper 1S0808

Social Sciences